TRICONTINENT™
HANDLING LIQUIDS...PRECISELY

C-Series Precision Pump (C3000/C24000)

Software Manual

8694-12 A

C-Series Software Interface

Table of Contents

Document History

Date	Changes
05/18/11	• Added additional C1200 and C24000 pump configuration information • Updated Table 3 OEM Protocol communication details • Corrected argument limits for [k] command • Updated valve position Figures 2, 4 and 5 Updated for changes to 08691-10V8 (C3000:062111) firmware • Added two low level valve move commands >[nn] and <[nn] • [i]<n> command added to control the optional auxiliary +24V solenoid output • ?45 Report command added • [u_17], [u_18], [u_19] nd [u_20] EEPROM configuration parameters added • [u_5] EEPROM configuration parameters modified • Default setting for 4-port valve configuration EEPROM parameter, u_11. Changed from 2103001 to 213001. This swaps the Bypass and Extra position on a 4-port valve. Figure 2 updated accordingly • Made changes to [k] command • Made changes to [H] command • Changed Aux LED designators figure 6 • Added command [11] to the CAN buss Report/Answer commands
05/13/10	Updated for changes to 08691-10V7 firmware (C3000:051310) • [U1] sets 3-port Y valve (4-port jumper also removed) • [U2] sets 4-port 90 deg valve (4-port jumper installed) • [U4] sets 4-port 90 deg distribution valve (I, O, B, E commands 4-port jumper also required) • [U5] T valve(4-port jumper also required) • [U11] Set 3-port distribution valve I<n>, O<n> commands. • [I]<n> Moves the valve to port <n> in a CW direction • [O]<n> Moves the valve to port <n> in a CCW direction • ?6 reports valve port (1, 2 or 3) instead of I, O, B and E • Allow velocity and acceleration to be set in micro-step units. Added the [N]<2> argument to the [N] command. N<2> gives the ability to set velocities and acceleration in micro-steps. ?11 reports the micro-step status. In [N]<2> mode the max arguments of velocity/acceleration commands are increased by 8: A) L<1-160>. In non-microstep mode L<1-20> B) V<1-48000>. In non-microstep mode V<1-6000> C) v<0-8000>. In non-microstep mode v<0-1000> • Fixed some mistakes in the CAN Interface section • Added EEPROM parameter [u_15] to accommodate new lead screw pitches • Fixed a bug with the [j]<n> command. The last digit in the argument, which sets the auxiliary outputs, was not being parsed correctly • The [H] command, which halts program execution based on the 2 auxiliary inputs, was modified. When halted, the firmware waits for the falling edge of the respective input. Previously, the inputs were level sensitive • Fixed a bug where the valves would not respond correctly to the I and O commands if no initialization command [Z] or [Y] was given • All spaces are ignored in a command string • The number of character allowed in a EEPROM string was increased from 100 to 128 • Added the ?7, report acceleration slope • Default Initialization speed, previously hard coded to 1400, is now the same as the default Vmax (u3) EEPROM setting • Added ?19. If pump is not initialized with a z or similar command, will report 0. Reports 1 if initialized • Default Dead Volume of 4mm lead screw changed to 64 (u9_64) • Maximum argument for the dead volume <k>increased from 80 to 255

	• Maximum argument for the backlash <K> increased from 31 to 100 • At V = 500Hz, motor resonance with certain mechanical configurations of multiple pumps would give false plunger overload errors. The Hystersysis value was increased from +/-4 Counts (+/-78mV) to +/-10 Counts (+/-196mV)
08/11/09	Updated for changes to 08691-10V6 firmware
6/16/09	• Updated C3000 RS232 command summary • Updated for changes to 08691-10V5 firmware
1/30/09	• Updated to reflect changes with firmware version C3000: 012109 • Commands [n] [j] and [?21] added • Valve port positions (Input, Output, Bypass and Extra) vs. motor shaft position can be mapped into the EEPROM. Added commands U10 and U11 commands • Default Valve positions for a 4-port valve changed The “Bypass” and “Extra” are swapped. u11 is set to u11_2103001. To set to the previous C3000 configuration set: u11_2130001 • For a 4 position valve. Any 180 degree moves are done in a Counterclockwise direction after a ‘Z’ initialization command is issued. If a ‘Y’ initialization command is issued, any 180 degree valve moves are done in a clockwise rotation • Removed various unused EEPROM parameters. [u] Command modified • Fixed errors in table 3.8 • Fixed various typos
11/07/08	• Fixed misprint with L command
11/03/08	• Updated Command V and command C to explain round-off error

C-Series (C3000/C24000) Hardware Communication Interface

The C-Series has three separate communication interfaces:

1) RS485

2) RS232

3) CAN

RS232 and RS485 are identical from a software standpoint. The main difference between the two is that RS485 can communicate to more than one pump. RS232 is limited to a single pump communication. RS485 is sometimes referred to as multi-drop, whereas RS232 is single drop.

The C-Series has a built in RS232 to RS485 converter. This allows for an RS232 connection to the host computer and RS485 connection to any additional pumps.

CAN communication is completely different from RS232/RS485. Not only is the hardware layer different, but the software protocol is unique. Please refer to CAN bus section for more detail.

C-Series Addressing Scheme

As part of the communication protocol, an address for each pump must be specified. The user has the option of addressing a single pump, two pumps (dual device), four pumps (quad device), or all 15 pumps (all devices), depending on the address byte used. Each physical address on the address switch corresponds to a hexadecimal value, as shown in Table 3-1.

Table 1. Hexadecimal Addressing Scheme

Address (hex)		Device
RS232/ RS485	CAN	
30	0	Master Address (master controller, personal computer, etc)
31..3F	1..F	Addresses single device
41..4F	N/A	Addresses two devices at a time (dual device)
51..5D	N/A	Addressed four devices at a time (quad device)
5F	N/A	Addresses all devices on the bus

For example, a C-Series with address switch set to 0 is addressed as device “31h” in the RS232 or RS485 communication protocol, hardware address 1 is addressed as device “32h”, and so on.

Table 2 shows the different address switch settings for each of these configurations.

Table 2. Address Switch Settings in Hex (ASCII)

Switch Setting	Single Device		Dual Device		Quad Device		All Devices	
	Hex Address	ASCII Address	Hex Address	ASCII Address	Hex Address	ASCII Address	Address	Value to Send
0 1	31 32	1 2	41	A	51	Q	5F	-
2 3	33 34	3 4	43	C				
4 5	35 36	5 6	45	E	55	U		
6 7	37 38	7 8	47	G				
8 9	39 3A	9 :	49	I	59	Y		
A B	3B 3C	; <	4B	K				
C D	3D 3E	= >	4D	M	5D	]		
E	3F	?	4F	O				
F	Self Test							

The user can communicate with all pumps in the chain by using address “5Fh”, for example, to initialize all pumps at once. Then each pump can be controlled independently by using addresses “31h” to 3Fh.”

NOTE: Multiple address commands cannot be used to determine device status, nor will they respond to Report commands. Each device must be queried separately.

Communication Protocols

Three communication protocols are available:

- OEM communications protocol
- Data Terminal (DT) protocol
- CAN protocol

NOTE: The C-Series firmware automatically detects the OEM, DT or CAN communication protocol. The Baud rate (9600 or 38400) is not automatically detected and needs to be set correctly.

The DT (Data Terminal) protocol is designed to be used with a Terminal emulator program such as HyperTerminal, which comes installed with Microsoft Windows. For instructions on using a Microsoft Windows Terminal Emulator, see “Using DT Protocol with Microsoft Windows” in this chapter.

TCS Commander software can also be used to communicate in either DT or OEM mode.

NOTE: If not using a Terminal program, TriContinent recommends using the OEM protocol. It provides increased error checking and recovery.

OEM Communication Protocol

OEM communication is a robust protocol that includes automatic recovery from transmission errors. Table 3 describes each setting within the OEM communication protocol.

Table 3. OEM Protocol Communication Details

Parameter	Setting
Character Format	
Baud Rate	9600 or 38400
Data Bits	8
Parity	None
Stop Bit	1
Command Block (see "OEM Protocol Command Block Characters" for details)	
1	SYNC (FFh)
2	STX (Crtl B or 02h)
3	Pump Address
4	Sequence Number
5+n	Data Block (length n)
6+n	ETX (Crtl C or 03h)
7+n	Checksum
Answer Block (see "OEM Protocol Answer Block Characters" for details)	
1	STX (Crtl B or 02h)
2	Master Address (0 or 30h)
3	Status Code
4+n	Data block (length n bytes)
5+n	ETX (Crtl C or 03h)
6+n	Checksum

OEM Protocol Command Block Characters

The command block characters in the OEM communication protocol are described below. All characters outside the command block are ignored.

When developing a parsing algorithm, the programmer should key on the STX as the beginning of the answer block and the checksum (character after ETX) as the end of the answer block.

SYNC (FFh)

Used for backward compatibility with older model pumps.

STX (^B or 02h)

The STX character indicates the beginning of a command string.

Pump Address

The pump address is specific, set by the rotary switch, for each individual pump.

NOTE: The pump's address is the rotary switch setting on the back of the pump plus one. For example, if the switch is set to 0, the pump's address is 1 or "31h".

Sequence Number/Repeat Flag

The sequence number is a single byte that conveys both a sequence number (legal values: 0 to 7) and a bit-flag indicating that the command block is being repeated due to a communications breakdown. The sequence number is used as an identity stamp for each command block. Since it is only necessary that every message carry a different sequence number from the previous message (except when repeated), the sequence number may be toggled between two different values (e.g., “1” and “2”) as each command block is constructed. During normal communication exchanges, the sequence number is ignored. If, however, the repeat flag is set, the pump compares the sequence number with that of the previously received command block to determine if the command should be executed or merely acknowledged without executing.

NOTE: If the operator chooses not to use this option, the sequence number can be set to a fixed value of 1 (31h).

The following two scenarios clarify this error detection mechanism.

Scenario 1

1. The computer sends a command block stamped with sequence #1 to the pump.

2. The pump receives the command, sends an acknowledgement to the PC, and executes it.

3. Transmission of the acknowledgement message is imperfect; the PC does not receive it.

4. The PC waits 100 ms for the acknowledgement then retransmits the command block with the sequence number left at 1 and the repeat bit set to indicate a retransmission.

5. The pump receives the transmission, identified as such by the repeat bit.

6. The pump checks the sequence number against that of the previously received command block, Noting a match, the pump sends an acknowledgement to the PC, but does not execute the command (since it has already been executed).

7. The PC receives the acknowledgment and continues with normal communications.

8. The next command block is stamped with sequence #2 to indicate a new command.

Scenario 2

1. The computer sends a command block stamped with sequence #1 to the pump.

2. The pump never receives the command due to a communication error and thus does not send an acknowledgement to the PC.

3. The PC waits 100 ms for the acknowledgement then retransmits the command block with the sequence number left at 1 and the repeat bit set to indicate a retransmission.

4. The pump receives the retransmission, identified as such by the repeat bit.

5. The pump checks the sequence number against that of the previously received command block. Noting a mismatch, the pump recognizes this as a new command block and sends an acknowledgement to the PC. It then executes the command.

6. The PC receives the acknowledgement and continues with normal communications.

7. The next command block is stamped with sequence #2 to indicate a new command.

The sequence number/repeat byte is constructed as follows:

Bit #	7	6	5	4	3	2	1	0
Value	0	0	1	1	REP	SQ2	SQ1	SQ0

REP: 0 for non-repeated / 1 for repeated

SQ0 – SQ2: sequence value, as follows:

Sequence Value	**SQ2**	**SQ1**	**SQ0**
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

Data Block (length n bytes)

The data block consists of an ACCII string of data or commands sent to the pump or host Certain commands, [Q] for example has a data block length of 0. That is, no data string exists.

ETX (^C or 03h)

The ETX character indicates the end of the command string.

Checksum

The checksum is the last byte of the message string. All bytes (excluding line synchronization and checksums) are XORed to form an 8-bit checksum. This is appended as the last character of the block. The receiver compares the transmitted value to the computed value. If the two values match, an error free transmission is assumed, otherwise, a transmission error is assumed.

OEM Protocol Answer Block Characters

The answer block characters in the OEM communication protocol are described below.

STX (^B or 02h)

The STX character indicates the beginning of a command string.

Master Address

The master address is the address of the host system. This should always be “30h” (ASCII “0”).

Status and Error Codes

The status and error codes define pump status and signal error conditions. For a description of status and error codes, see “Error Codes and Query Status”.

Data Block (length n bytes)

This is the response from all report commands with the exception of the [Q] command.

ETX (^C or 03h)

The ETX character indicates the end of the command string.

Checksum

The checksum is the last byte of the message string. All bytes (excluding line synchronization and checksums) are XORed to form an 8-bit checksum. This is appended as the last character of the block. The receiver compares the transmitted value to the computed value. If the two values match, an error free transmission is assumed; otherwise, a transmission error is assumed.

Data Terminal (DT) Protocol

The DT Protocol can be used easily from any terminal or terminal emulator capable of generating ASCII characters at 9600 or 38400 baud, 8 bits, and no parity.

Table 4. DT Protocol Communication Details

Character Format	
Baud Rate	9600 or 38400
Data Bits	8
Parity	None
Stop Bit	1
Command Block (see “DT Protocol Command Block Characters” for details)	
1	Start Character (ASCII “/” or 2Fh)
2	Pump Address
2+n	Data Block (length n)
3+n	End Character (Carriage Return ([CR] or 0Dh)
Answer Block (see “DT Protocol Command Block Characters” for details)	
1	Start Answer (ASCII “/” or 2Fh)
2	Master Address (ASCII “0” or 30h)
3	Status Character
3+n	Data block (if applicable)
4+n	ETX (03h)
5+n	Carriage Return (0Dh)
6+n	Line Feed (0Ah)

DT Protocol Command Block Characters

The command block characters in the DT communication protocol are described below.

Start Character

The start character (ASCII “/” or “2Fh”) indicates the beginning of a message.

Pump Address

The pump address is an ASCII character specific to each pump.

NOTE: The pump’s address is the rotary switch setting on the back of the pump plus one. For example, if the switch is set to 0, the pump’s address is 1 or “ASCII 31h”.

Data Block (length n)

The data block consists of the ASCII data or commands sent to the pump or host.

End Character

The end character indicates the end of the message.

DT Protocol Answer Block Characters

The answer block characters comprising the DT communication protocol are described below.

Start Answer

The start character (ASCII “/” or “2Fh”) indicates the beginning of the response.

Master Address

The master address is the address of the host system. This should always be “30h” (ASCII “0”).

Status Character

The status and error codes define pump status and signal error conditions. See the description of the [Q] command in “Error Codes and Query Status”.

Data Block

This is the response from all report commands with the exception of the [Q] command.

ETX (^C or 03h)

The ETX character indicates the end of the command string.

Carriage Return (0Dh) and/or Line Feed (0Ah)

This character terminates the reply block.

Using DT Protocol with Microsoft Windows HyperTerminal Program

The C-Series can be controlled in DT protocol mode directly from the Microsoft Windows HyperTerminal accessory.

To communicate with the C-Series using Windows XP HyperTerminal, follow these steps:

1. To connect the C- Series to a communication ports on the PC, first select the Start->All Programs->Accessories->Communications->HyperTerminal

2. Enter a name for the connection and select an icon, then click OK. The Phone Number dialog box appears.

3. Select the following in the field provided:

   Connect using: <Correct COM port> (Usually Com1 or Com2)
   Click OK. The COM Properties dialog box appears.

5. Select the following in the fields provided:
   Bits per second: 9600 or 38400 (jumper selectable, factory default = 9600)
   Data bits: 8
   Parity: None
   Stop bits: 1
   Flow control: None

   Click: OK

6. Select the File menu, and choose Properties. The properties dialog box appears.

7. Select the Settings tab, and enter or select these options:

   Function, arrow, and Control keys act as:
   - Select “Terminal keys”

   Emulation:
   - Select “Autodetect”
   - Enter “500” in Backscroll buffer lines
   -

   Click the ASCII Setup button. The ASCII Setup dialog box appears.

8. Enter or select these options:
   - Select “Send line ends with line feed:
   - Select “Echo typed characters locally”
   - Enter a Line delay of “0”
   - Enter a Character delay of “0”
   - Select “Wrap lines that exceed terminal width”

9. Click OK to close the ASCII Setup dialog box, then click OK to close the Properties dialog box.

10. Set the pump address to 1 (rotary switch on back to 0) or the appropriate address. Ensure that the Baud rate jumper is set correctly.

11. Power on the pump and initialize it by typing “/1ZR” and pressing Enter.

To run the pump, see the commands listed in “Using the C-Series Command Set Description”.

CAN Interface Communications

Can (Controller Area Network) is a two-wire, serial communication bus. It eliminates polling sequences to verify task completion. Using CAN, the pumps asynchronously report to the master, or host, when they have finished the current task.

NOTE: All TriContinent C-Series use CAN controller chips compatible with Philips Semiconductor CAN bus specification, version 2.0.

CAN Messages

CAN messages consist of frames. Each frame has an 11-bit Message Identifier (MID), followed by a RTR bit and then a 4-bits to indicate the data length, and finally by up to 8 bytes of data. If more than 8 bytes of data are required to be transferred, a multi-frame Message must be used

Can Message Frame

MESSAGE ID (MID)				Data Block (up to 8)			
Dir	Group	Device	Frame	RTR	EXT	Data Length code	Data byte 0 8
1 bit	3 bits	4 bits	3 bits	1 bit	1 bit	4 bits	0 bits .....64 bits

CAN Message Construction

Each message frame begins with the 11 bit MID. The data block (up to 8 bytes in length) follows the MID and length information. The MID makes up three nibbles that are transmitted first in a message frame. The bits are grouped as shown:

MID

Dir (1 bit)
This is the direction bit. It lets the devices on the bus know whether the current message is to or from the master. “0” means that the message is from master to slave; “1” means the message is from the slave to the master.

NOTE: Peer-to-peer messaging not supported.

Group (3 bits)
This is the group number (0 – 7). Each type device on the CAN bus has a group assignment. The C-Series is assigned to group 2. The group number “1” is reserved for the boot request procedure.

Device (4 bits)
This is the address of the module in the particular group. Each group can have up to 16 devices. The address value is 0 – 15.

Frame Type (3 bits)
This lets the device know what type message is coming. See “CAN Frame Types”.

RTR (1 bit)
This bit is not used in TriContinent’s CAN implementation and should always be set to 0.

EXT (1 bit)
This bit is should always be set to 0. Extended Frames are not allowed.

Data Length Code (DLC)
This is the length of the data block in the message. Data blocks can be from zero to eight bytes in length.

Data Block(s)
From 0 to 8 bytes can be transmitted in a single frame.

CAN Frame Types

The frame types allow each device to know what type of command is coming in and enables faster processing of commands. Pumps respond to the frame types described below.

“On-the-Fly” Commands (V and T)

Normal commands use a frame type 0 of “1” (i.e., “Action Commands”). Since commands sent over the CAN bus with a particular frame type must complete before a subsequent command using the same frame type can be issued, a different ID must be used when issuing an “on-the-fly” command. For this reason, “on-the-fly” commands must be issued over the CAN bus with a frame type of “0” (zero).

When using “on-the-fly” commands, the “frame type 0” commands will not generate completion messages and thus no pairing code is needed (these commands are simply acknowledged immediately).

Action Frames, Type 1

This frame type is used for action commands, such as Initialization commands, Movement commands, Valve commands, or to set pump operating parameters. All “task-type” commands are sent in this type message frame. When multi-frame messages are used to send an action command, this frame is the end message sent to the pump.

Common Commands, Type 2

The frame type is set to 2 and the command is a single ASCII character in the data block. The single ASCII character is described below.

Command	Description
0	Reset mode. This resets the pump and begins the boot request procedure.
1	Start loaded command. Just like sending an [R] command after a string has been loaded.
2	Clear loaded command. This clears out the command buffer.
3	Repeat last command. This command does the same thing as the [X] command.
4	Stop action immediately. This acts like [T] command.

Multi-Frame Start Message, Type 3

This frame type lets the pump know that the next message will be longer than the 8-byte maximum for each frame. Subsequent frames will follow to complete the message.

Multi-Frame Data, Type 4

This frame type is used to identify a frame in the middle of a multi-frame message. The last frame of a multi-frame message for action commands must be type 1. The last frame of a multi-frame message response from the pump for report commands will be type 6.

NOTE: There is no type 5 frame

Report/Answer Commands, Type 6

This frame type is used to get information back from the pump. It is similar in operation to the query commands (i.e. [?]) used in the OEM and DT protocols. The report command is one byte long and is a single ASCII character in the data block. Report commands in ASCII format are:

Command	Description
0	Report calculated plunger position in steps (standard/microstep). Like the [?] RS232 command
1	Report linear encoder position in increments, like the [?4] command.
2	Report current plunger position in steps (standard/microstep), like the [?5] command
3	Report current valve position in mnemonics, like the [?6] RS232 command; i=input, b=bypass
4	Report plunger end velocity in Hertz per half-step, like the [?2] RS232 command
6	Report start velocity, like the [?1] command
7	Report cutoff velocity, like the [?3] command
10	Report buffer status, like the [?10] and [F] RS232 commands: 0=empty.1=commands in the buffer
11	Report acceleration, like the [?7] command.
12	Report number of backlash steps, like the [?12] RS232 command.
13	Report status of input #1. Like the [?13] RS232 command
14	Report status of input #2, like the [?14] RS232 command
15	Nonfunctional, always returns to 1
16	Nonfunctional, always returns to 1
17	Nonfunctional, always returns to 1
18	Nonfunctional, always returns to 1
19	Report if pump is initialized. 1 = initialized, 0 = not initialized
20	Report checksum, like the [?20] and [#] commands
22	Report liquid sensor value *Nonfunctional command, always returns 255*
23	Report firmware version, like the [?23] and [&] RS232 commands
24	Report zero gap steps, like the [?24] RS232 command
29	Report current status, like the [Q] RS232 command

When the pump responds to a query, the first byte of the data block is the status byte. It is defined like the status byte in the RS232 and RS485 protocols. The next byte is a null character. The remaining six bytes are for the response in ASCII. If the pump is only reporting current status, the message is only two bytes long. If the reply consists of more than six bytes, multi-frame messages are used.

CAN Data Block

The data block tells the pump what to do. Pump commands are sent in ASCII just like in RS-232 or RS-485. For command strings that are more than eight bytes in length, multi-frame messages are used. This permits long program strings to be sent as with other communications interfaces.

Handling of Pump Boot Requests

When the pump is first powered up or receives a system reset command (frame type, command 0), the pump notifies the host of this condition by sending a boot request message at 10 to 12 second intervals until it receives a proper response. The group number is 1 for the boot request message. The frame type is 2 when the pump sends messages to the host, and the frame type must be 0 when the host replies to the boot request.

Example 1. The pump is set to address 0

Pump sends:

Dir	Group	Device	Frame	RTR	Length
1	001	0000	010	0	0000

MID = 100 1000 0010 = 482 (hex)

Host acknowledges:

Dir	Group	Device	Frame	RTR	Length	Node ID	Slave ID
0	001	0000	000	0	0010	0010 0000	0010 0000

MID = 000 1000 0000 = 080 (hex)

Host acknowledges the boot request with:

Dir = 0	Host to slave
Group = 1	Boot request response group
Device = 0	Always 0 in boot response
Frame = 0	Boot request response frame
Rtr = 0	Always 0
Length = 2	Two data bytes in return message

Node ID	Group ID (2) + Pump Address (0)	20 (hex)	Must resend with Group & Address
Slave ID	Same as Node ID	20 (hex)	

Example 2. The pump is set to address 6

Pump sends:

Dir	Group	Device	Frame	RTR	Length
1	001	0110	010	0	0000

MID = 100 1011 0010 = 4B2 (hex)

Host acknowledges:

Dir	Group	Device	Frame	RTR	Length	Node ID	Slave ID
1	001	0000	000	0	0010	0010 0110	0010 0110

MID = 100 1000 0000 = 480 (hex)

Host acknowledges the boot request with:

Dir = 0	Host to slave
Group = 1	Boot request response group
Device = 0	Always 0 in boot response
Frame = 0	Boot request response frame
Rtr = 0	Always 0
Length = 2	Two data bytes in return message

***NOTE**: Boot MID is the same for all nodes*

Node ID	Group ID (2) + Pump Address (6)	& (ASCII)	26 (hex)
Slave ID	Same as Node ID	& (ASCII)	26 (hex)

CAN Host and Pump Exchanges

When a slave pump receives a command, finishes a command, encounters an error condition or responds to a query, its sends an answer frame to the host using the same frame type as the command it belongs to. The answer frame format is device dependent. Generally, it will have the following format:

{MID} {DLC}{Answer}

Where:

{MID}: 11-bit message identifier. The direction bit is 1. The group number and the frame type are the same as received. Device is the current device address.

{DLC}: 4-bit data length code.

{Answer}: Data bytes block. The first byte of the data block is always the status byte. It is defines as in Table 8. The second byte is a null character. The remaining bytes contain the response in ASCII format. If the reply consists of more than six bytes, the multi-frame messages are used.

NOTE: Only one command of a given frame type can be in progress at any one time: e.g., after issuing a command to a slave pump with frame type = 1, the master must wait for the answer with frame type = 1 before issuing the next command with frame type = 1. If the user insists on sending the command, a command overload status results. Several commands with different frame types can be in progress at the same time; e.g., an action command and a query command.

Following are typical exchanges between the host and slave for action commands, multi-frame commands, common commands, and query commands.

Action Command

The host commands [ZR] a pump, and the pump is set to address 0.

Host sends:

0	010	0000	001	0	0010	ZR
Dir	Group	Device	Frame Type	RTR	DLC	Data Bytes

Pump Acknowledges:

1	010	0000	001	0	0000
Dir	Group	Device	Frame Type	RTR	DLC

After executing the command, pump reports status:

1	010	0000	001	0	0010	60 00 (hex)
Dir	Group	Device	Frame Type	RTR	DLC	Data Bytes

Multi-Frame command

The host commands [Z2S51A3000OgHD300G10G5R] to a pump, and the pump is set to address 0.

Host sends:

0	010	0000	011	0	1000	Z2351A30 (ASCII)
Dir	Group	Device	Frame Type	RTR	DLC	Data bytes
0	010	0000	100	0	1000	00IgHD30 (ASCII)
Dir	Group	Device	Frame Type	RTR	DLC	Data bytes
0	010	0000	001	0	0111	0G10G5R (ASCII)
Dir	Group	Device	Frame Type	RTR	DLC	Data bytes

Pump acknowledges:

1	010	0000	001	0	0000
Dir	Group	Device	Frame Type	RTR	DLC

After executing the command, pump reports status:

1	010	0000	001	0	0010	60 00 (hex)
Dir	Group	Device	Frame Type	RTR	DLC	Data bytes

NOTE: For multi-frame commands, the pump only acknowledges the last frame.

Common Command

After the host has sent command [A1000A0] to the pump, it sends command 0 of frame type 2 to a pump and makes the pump move. The pump is set to address 0.

Host sends:

0	010	0000	010	0	0001	0
Dir	Group	Device	Frame Type	RTR	DLC	Data bytes

Pump acknowledges:

1	010	0000	010	0	0000
Dir	Group	Device	Frame Type	RTR	DLC

After executing the command, pump reports status:

1	010	0000	010	0	0010	60 00 (hex)
Dir	Group	Device	Frame Type	RTR	DLC	Data bytes

Query Command

The host sends command report 29 of frame type 6 to a pump, and the pump is set to address 1.

Host sends:

0	010	0001	110	0	0010	29 (hex)
Dir	Group	Device	Frame	RTR	DLC	Data bytes

Pump reports:

1	010	0001	110	0	0010	60 00 (hex)
Dir	Group	Device	Frame	RTR	DLC	Data bytes

NOTE: For query commands, no acknowledge frame is needed.

The host sends command report 23 of frame type 6 to a pump, and the pump is set to address 1.

Host sends:

0	010	0001	110	0	0010	23
Dir	Group	Device	Frame Type	RTR	DLC	Data bytes

Pump reports:

1	010	0001	011	0	1000	60 00 00 (hex)C300 (ASCII)
Dir	Group	Device	Frame	RTR	DLC	Data bytes
1	010	0001	100	0	0111	00 024 00 (hex) O 10(ASCII)
Dir	Group	Device	Frame	RTR	DLC	Data bytes
1	010	0001	110	0	0111	00 024 00 (hex) 0109(ASCII)
Dir	Group	Device	Frame	RTR	DLC	Data bytes

NOTE: For a multi-frame reply, the start frame is type 3, the middle frame is type 4, and the last frame is type 6.

C-Series Command Set Description

The C-Series features a robust command set which allows a wide range of pump actions. Many of the commands have default arguments; however, the default values may not provide the optimal settings for your application. Take a moment to familiarize yourself with each command in order to obtain the best performance for your application.

For a quick summary of all commands, see the “Command Quick Reference”.

When problems are detected, the C-Series sends an error code. The error codes are described in C-Series Error Codes section.

Command Execution Guidelines

To use the commands properly, keep the following in mind:

- All commands, except Report commands and most Control commands must be followed by a [R] (Run or Execute) command.

- Single or multiple command strings can be sent to the pump.

  For example:
  - A single command such as [A3000R] moves the plunger to position 3000.

  - A multi-command string such a [IA3000OA0R] moves the valve to the Input position, moves the Plunger to position 3000, turns the valve to the Output position, and finally returns the Plunger to position 0.

- The pump’s command buffer holds a maximum of 255 characters. If a command is sent without the [R] Run command, it is placed into the buffer without being executed. If a second command is sent before the first command is executed, the second command overwrites the first command. That is, the first command string is erased.

- Once a command is executed, new commands are not accepted until the sequence is completed. If a new command is issued while the pump is busy, an error code will be returned. Exceptions to this rule include the [T] (Terminate), [V] (Set Top Velocity) and all Report commands.

- When a command is sent, the pump answers immediately. If an invalid command has been sent in a command string, the pump reports an error immediately. If there was an invalid parameter, In certain cases, the string will execute until the invalid parameter and then stop. In this case, the [Q] (Query) command can be used to read back the error to the host computer.

- Always run liquid through the syringe and valve when issuing a Move command. Failure to do so will eventually wear out the valve and syringe seal.

- Keep fingers out of the syringe slot while the pump is running. Failure to do so can result in injury.

Command Syntax

The syntax for each command in the command set is:

[command]	Square brackets [ ] are used to distinguish commands and should not be sent as part of the command string.
<n>	Command argument. n must be a value within the specified range.
0...6000	Valid range of numerical <argument>
(n)	Default <argument>, if no argument is given
{n}	Power up default value

NOTE: All commands are case sensitive

Initialization Commands

NOTE: On power up, the C-Series automatically homes the Valve motor. This feature can be disabled by using the pump configuration command [u_].

Initialization Sequence

Initialization sequence, in response to the [Z] or [Y] command, is as follows:

1) Valve is homed to output right position with the [Z] command, or output left with the [Y] command.
2) Syringe motor speed, and stall force are set by Z<n> or Y<n> arguments.
3) Valve to Output, Plunger moves up until home opto is tripped, this step is skipped if the plunger is already at the top of stroke.
4) Plunger is then stalled at the top of the syringe.
5) Valve to Input, the syringe then travels downward a fixed number of steps.
6) Valve to Output, syringe moves up and stops at Syringe Dead volume <k> steps away from the stall position.

The output position of the valve is assigned to the left or right side, depending upon the Initialization command [Z] or [Y], and all syringe velocity parameters [V], [v], [c] and [L] are reset to default values. Microstep mode [N] retains its value.

The force and speed at which the plunger stalls against the top of the syringe can be controlled via the Z<n>, Y<n>, or W<n> arguments.

Z<n1,n2,n3> Initialize Pump, Set Valve Output to the Right or CW polarity

The [Z] command initializes the plunger drive and sets a non-distribution type valve output to the right (as viewed from the front of the pump).

If a distribution valve is selected, <n2> and <n3> select the input and output ports. Valve movement is done as CW (clockwise) motion.

<n1>	0...40	
<n2>	0-X	Set the initialization input port on distribution valves. X = number of ports
<n3>	0-X	Set the initialization output port on distribution valves. X = number of ports
(n1)	0	Default argument
(n2)	1	Default argument
(n3)	X	Default argument, X = number of ports

The argument <n1> is described below:

Argument <n1>	Description
0	Initializes at full plunger force at speed 11 (default)
1	Initializes at half plunger force at speed 11
2	Initializes at one third plunger force at speed 11
3	Initializes at full plunger force and at speed 16
4	Initializes at full plunger force and at speed 18
5-9	Same as <n> = 0
10-40	Initializes at full plunger force and at the defined speed (see [S] command)

Z10-Z40 are initialization speeds which correspond to S10-S40 (Speed commands [S]), found in “Set Commands” later in this chapter. These commands can be used to change the standard initialization speeds. Slower initialization speeds may be useful when working with viscous fluids or small I.D. (inner diameter) tubing.

NOTE: The [Z] command resets the velocity settings ([V], [v] and [c]), acceleration [L] to power up defaults. The microstep mode [N] is preserved after a [Z] command.

The argument <n2> and <n3> are described below. **NOTE**: X = number of ports on the valve.

Argument <n2>	**Description**
0	Set the input initialization port to 1 (default)
1..X	Set the input initialization port

The argument <n3> is disabled below. **NOTE**: X = number of ports on the valve.

Argument <n3>	**Description**
0	Set the Output initialization port to X (default)
1..X	Set the Output initialization port

For <n2> and <n3> to be valid, an X port distribution valve must be selected. For a 3-port valve, U11 must be set. If a non-distribution valve is selected, the arguments are ignored.

Valve ports are numbered 1..X starting in a clockwise direction. See figure 5 for more details.

Y<n1,n2,n3> Initialize Pump, Set Valve Output to the Left or CCW polarity

The [Y] command initializes the plunger drive and sets a non-distribution valve output to the left (as viewed from the front of the pump).

If a distribution valve is selected, <n2> and <n3> select the input and output ports. Valve movement is done as CCW (counter clockwise) motion.

<n1> 0...40
<n2> 0-X Set the initialization input port on distribution valves. X = number of ports
<n3> 0-X Set the initialization output port on distribution valves. X = number of ports
(n1) 0 Default argument
(n2) 1 Default argument
(n3) X Default argument, X = number of ports

Argument <n1>	**Description**
0	Initializes at full plunger force at speed 11 (default)
1	Initializes at half plunger force at speed 11
2	Initializes at one third plunger force at speed 11
3	Initializes at full plunger force and at speed 16
4	Initializes at full plunger force and at speed 18
5-9	Same as <n> = 0
10-40	Initializes at full plunger force and at the defined speed (see [S] command)

Y10-Y40 are initialization speeds which correspond to S10-S40 (Speed commands [S]), found in “Set Commands” later in this chapter. These commands can be used to change the standard initialization speeds. Slower initialization speeds may be useful when working with viscous fluids or small I.D. (inner diameter) tubing.

NOTE: The [Y] command resets the velocity settings ([V], [v] and [c]), acceleration [L] to power up defaults. The microstep mode [N] is preserved after a [Y] command.

The argument <n2> is described below. **NOTE**: X = number of ports on the valve.

Argument <n2>	Description
0	Set the input initialization port to 1 (default)
1..X	Set the input initialization port

The argument <n3> is described below. **NOTE**: X = number of ports on the valve.

Argument <n3>	Description
0	Set the Output initialization port to X (default)
1..X	Set the Output initialization port

For <n2> and <n3> to be valid, an X port distribution valve must be selected. For a 3-port valve, U11 must be set. If a non-distribution valve is selected, the arguments are ignored.

Valve ports are numbered 1..X starting in a CCW direction. See figure 5 for more details.

W<n> Initialize pump without valve

The [W] command initializes the plunger drive but doesn't initialize the valve drive. [W] accepts the same <n1> arguments as the [Z] command.

w<n1,n2> Initialize valve only

The [w] command initializes the valve drive only.

The argument <n1> is described below. **NOTE**: X = number of ports on the valve.

Argument <n1>	Description
0	Set the input initialization port to 1 (default)
1..X	Set the input initialization port

The argument <n2> is described below. **NOTE**: X = number of parts on the valve.

Argument <n2>	Description
0	Valves homed in CW direction
1	Valves homed in CCW direction

For <n1> and <n2> to be valid, an X-port distribution valve must be selected. For a 3-port valve, U11 must be set. If a non-distribution valve is selected, the arguments are ignored.

k<n> Syringe Dead Volume command

The [k] command sets a gap between the plunger and syringe seal, also known as dead volume. The syntax for this command is:

<n> The offset in steps from the zero or stall position
<n> 0...120
<n> 0...960 in microstep mode
{24} Power up default C3000
{384} Power up default C24000

During initializations, the plunger moves upward until it contacts the top of the syringe, causing a forced stall initialization. The plunger then moves downward 120 full steps, and then upward 120 minus the <n> specified amount leaving a gap (dead volume), between the syringe seal and the top of the plunger. This small gap was designed so that the seal does not hit the top of the plunger each time the syringe moves to the home or zero position. This maximizes the life of the syringe seal.

Since [k] only takes effect on initialization, the [k] command is usually followed by an initialization command [Z], [Y], or [W].

Each time the unit is powered down, the [k] value will return to the default setting of {24}.

For example, to offset 10 full steps away from the zero position, send the following commands:

[k10ZR]

z<n> Simulated Plunger Initialization

The [z] command simulates an initialization of the pump, however, no mechanical movement of either the plunger or valve occurs. The position counter is set to <n>.

<n>	0…3000	in standard or non-microstep, mode.
<n>	0...24000	in microstep mode.
(n)	0	Default argument

Valve Movement Commands

I **Move Valve to Input position (non-distribution valves)**

The [I] command moves the valve on the C-Series to the Input position. The Input position can be either to the Left or the Right depending on the [Y] or [Z] initialization commands.

For example:

If the [I] command is sent after the [Z] command, the valve connects the syringe to the left side port (as viewed from the front of the pump).

Figure 1 shows the positions of the valves in relation to the initialization command and valve command used.

NOTE: a 3-port distribution can also be controlled using the standard [I], [O], [B] and [E] commands. [U]<4> must be set and the 4-port jumper must be installed. See figure 4 for more details.

I<n> **Move Valve clockwise to port <n> position (Distribution valves only)**

<n> 0…X , X = number of ports
(1) default argument

The [I]<n> command moves the distribution valve on a C-Series to the port <n> in a clockwise motion. [I]<0> sets valve to port 1.

A distribution valve is selected by using the U command. For example, a 3-port distribution valve is selected using [U11].

Figure 5 shows the positions of the valves in relation to the initialization command and valve command used.

O **Move Valve to Output position (non-distribution valves)**

The [O] command moves the valve on the C-Series to the Output position. The Output position can be either to the Left or the Right depending on the [Y] or [Z] initialization commands.

For example:

If the [O] command is sent after the [Z] commands, the valve connects the syringe to the right side port (as viewed from the front of the pump).

NOTE: a 3-port distribution can also be controller using the standard [I], [O], [B] and [E] commands. [U]<4> must be set and the 4-port jumper must be installed. See figure 4 for more details.

O<n> **Move Valve counter clockwise to port <n> position (Distribution valves only)**

<n> 1…X , X = number of ports
(X) default argument

The [O]<n> command moves the distribution valve on a C-Series to the port <n> in a clockwise motion. [O]<0> sets valve to port X.

A distribution valve is selected by using the U command. For example, a 3-port distribution valve is selected using [U11].

Figure 5 shows the positions of the valves in relation to the initialization command and valve command used.

B **Move Valve to Bypass position (non-distribution valves)**

The [B] command connects the Input and Output positions, bypassing the syringe.

NOTE: When the valve is in the Bypass position, the syringe plunger cannot be moved. Sending a Plunger Movement command causes an Error 11 (Plunger Move Not Allowed).

E **Move Valve to the Extra position (90°, non-distribution valves only)**

The [E] command moves a 90° valve to the extra position.

NOTE: This command is only applicable when the 4 position valve is selected. If a 4 position valve is not selected, this command is ignored. That is, it will return an error free response, but no valve movement will occur.

>[nn] **Moves the valve CW the specified number of steps**
For factory use only.

<[nn] **Moves the valve CCW the specified number of steps**
For factory use only.

Moves the valve CW or CCW the specified number of steps. 1 step = 0.9 degrees. Thus, to move 1 CW rotation = >400R

Figure 1. Valve Positions for the 3-Port, 120°, Valve

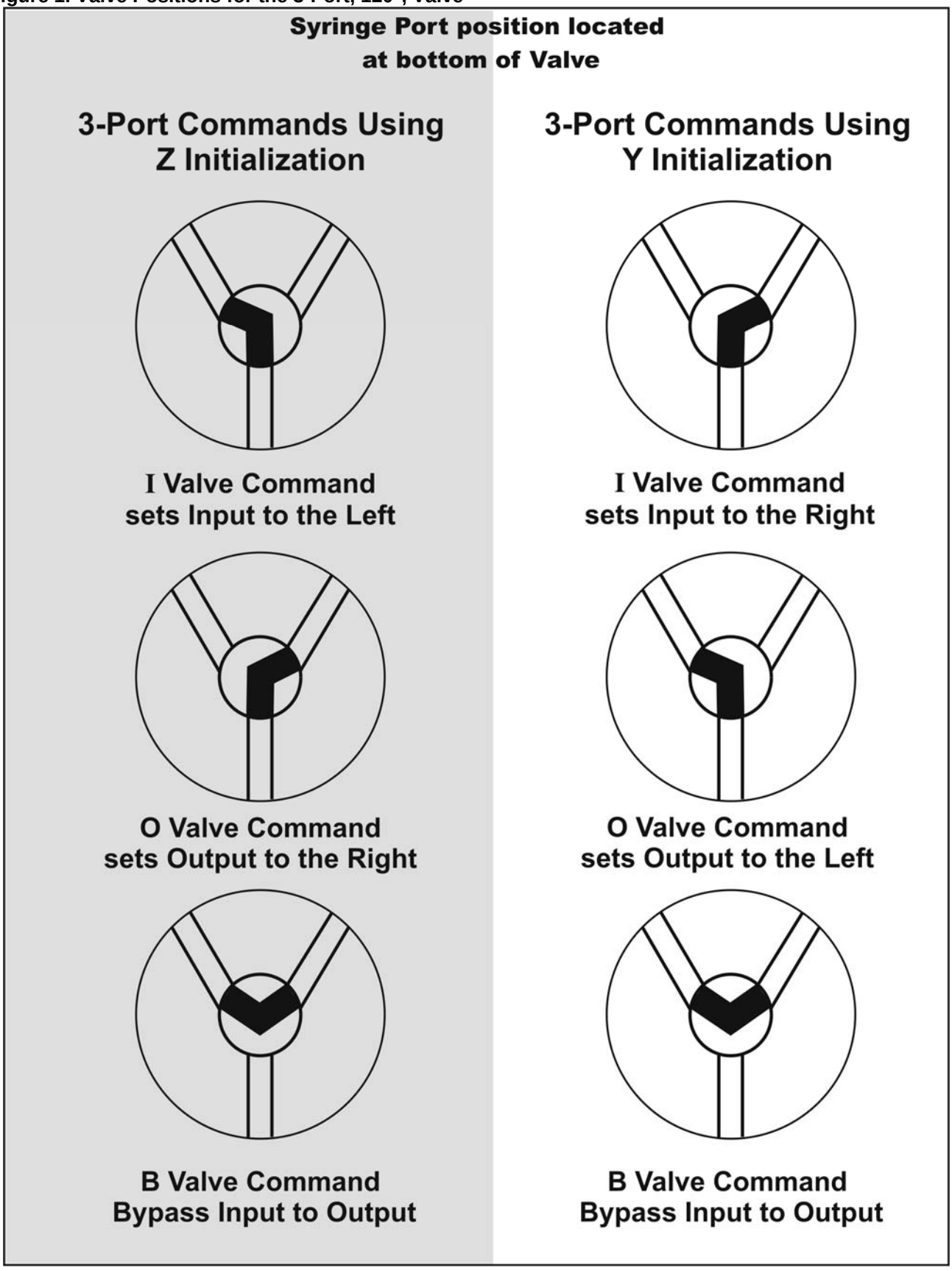


Figure 2. Valve Positions for the 4-Port, 90°, Valve (U2 set)

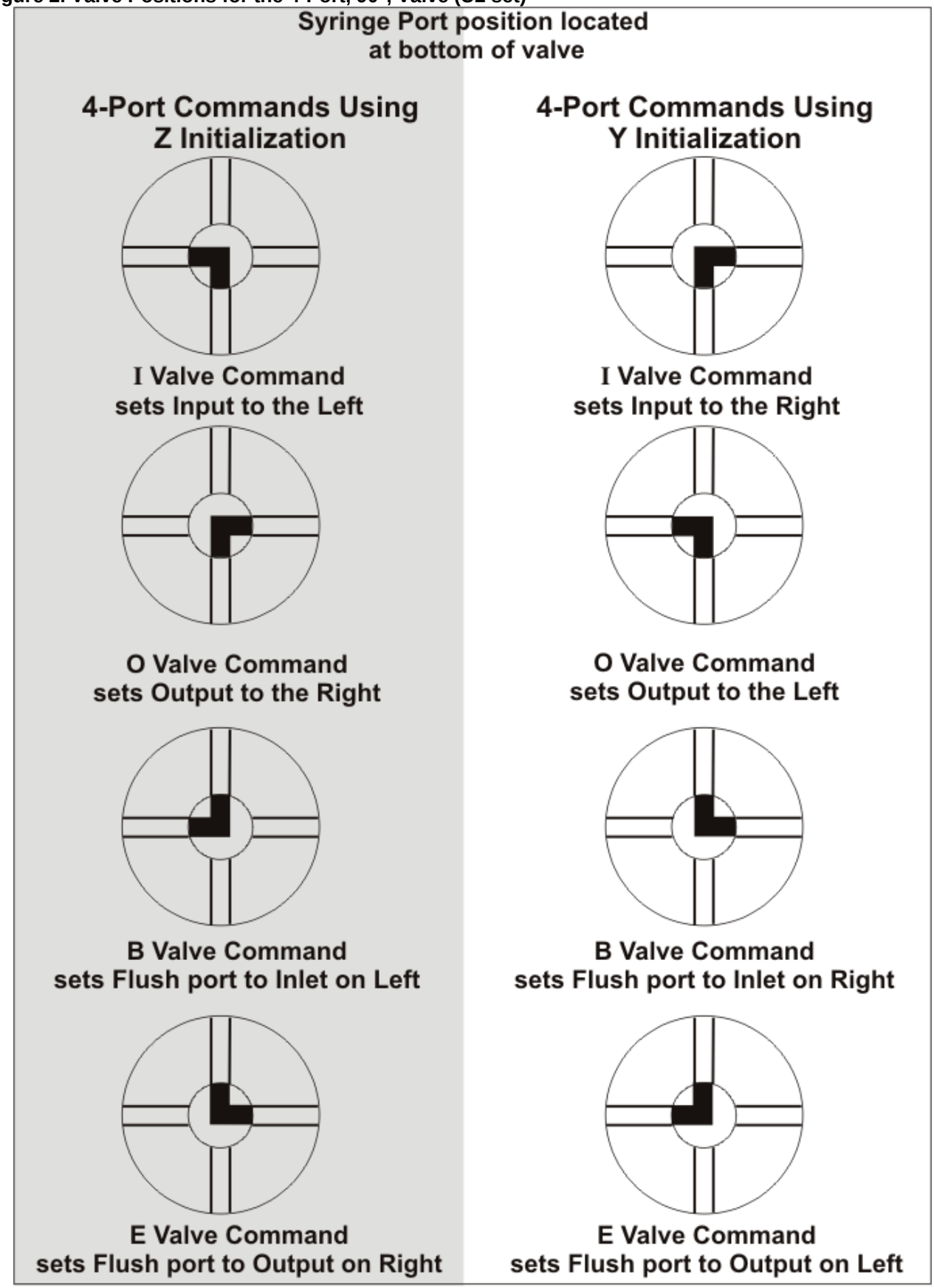


Figure 3. Valve Positions for the 3-Port T, 90°, Valve (U5 set)

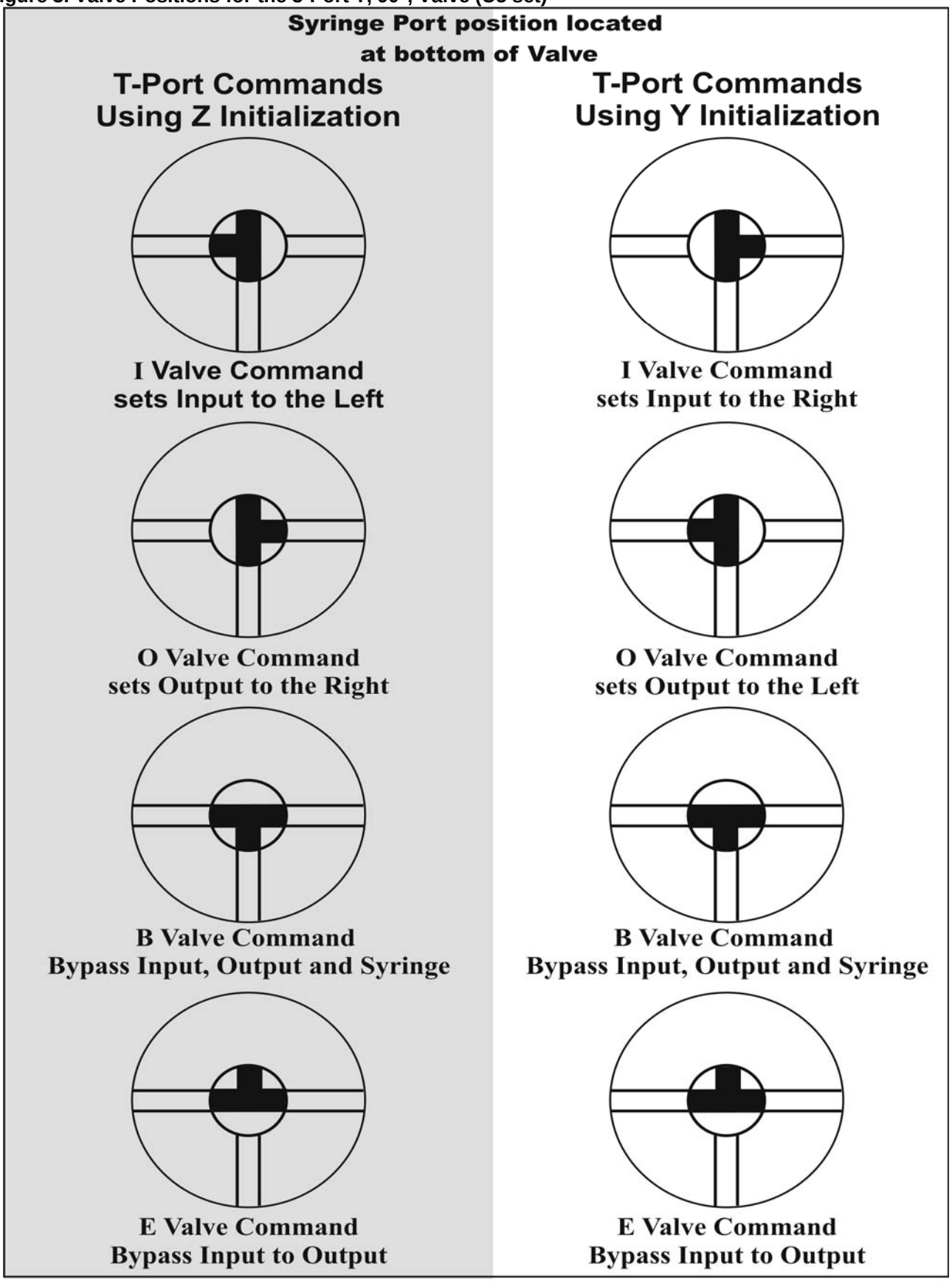


Figure 4. Valve Positions for the 4-Port Distribution, 90°, Valve (U4 set)

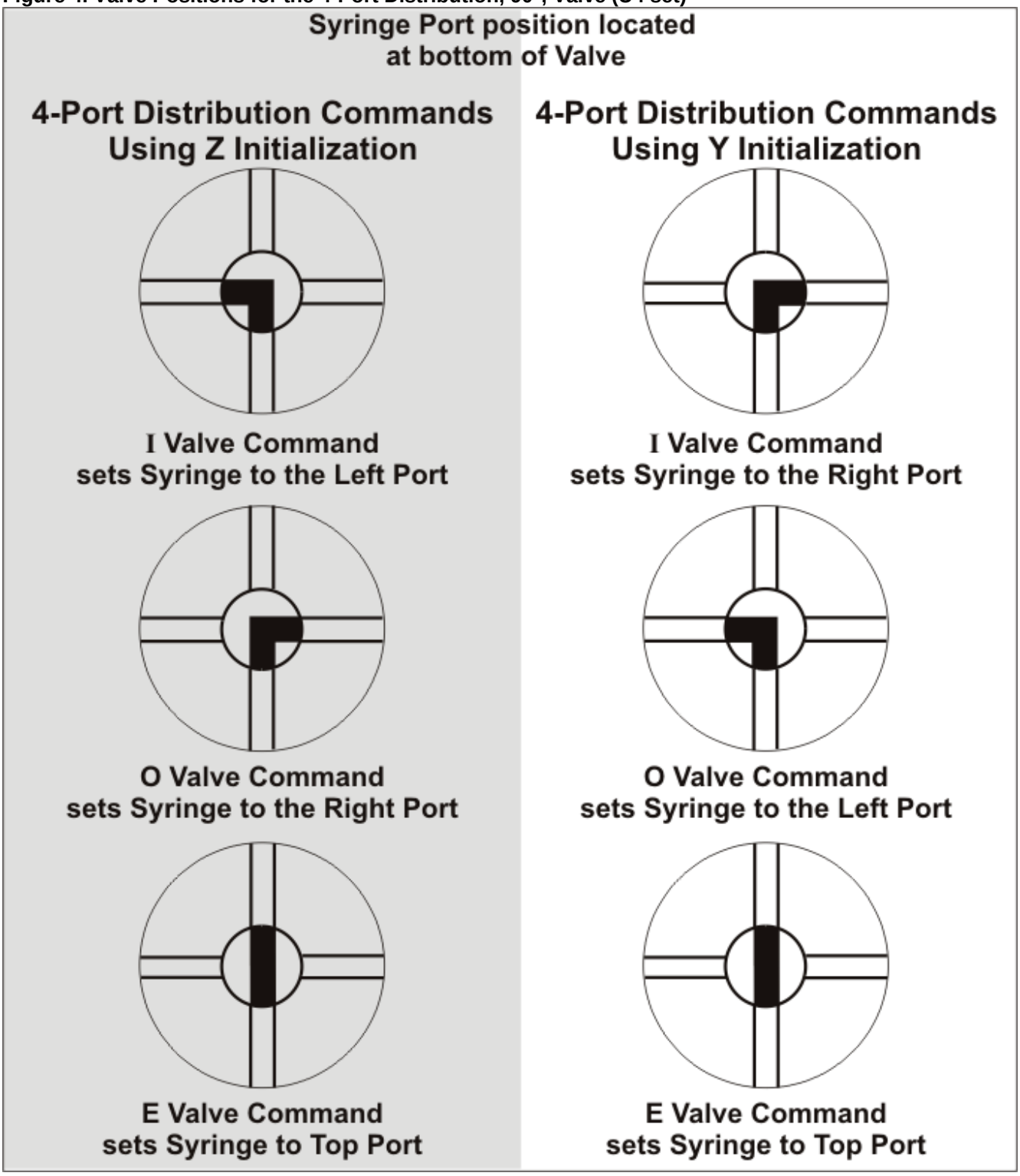
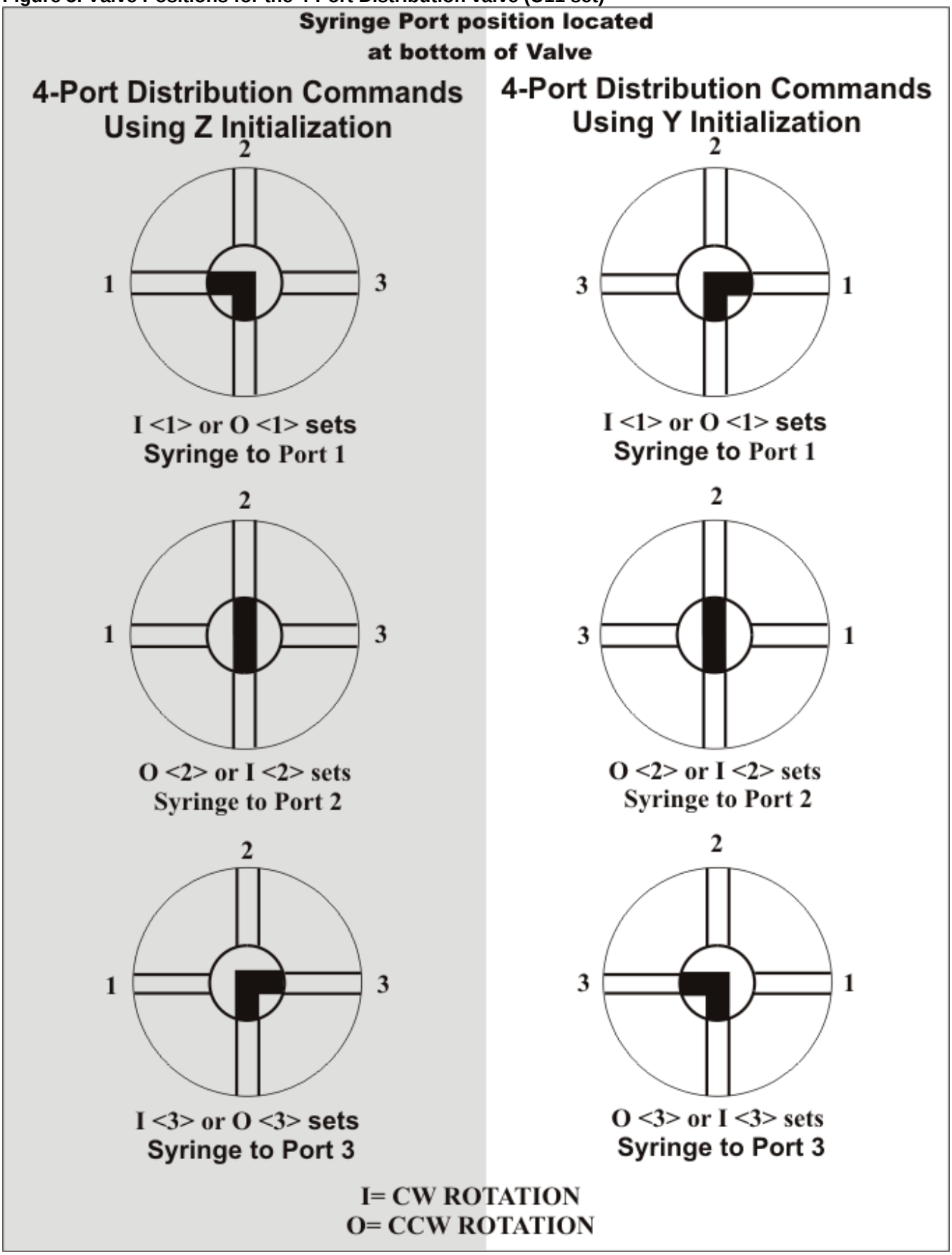


Figure 5. Valve Positions for the 4-Port Distribution valve (U11 set)



Plunger Movement Commands

NOTE: the range of the arguments can vary depending on the specific C-Series pump, C3000 or C24000.
The limits in the command descriptions are for the standard default C3000 configuration. For C24000 please substitute the limits in Table 5 below:

Table 5. Stroke for C3000 and C24000 configurations

Configuration	**Stroke non-micro-step mode (N0)**	**Stroke micro-step mode (N1 or N2)**
C3000 (u4_62, u12_0, u15_0)	3,000	24,000
Half-Step mode (u4_62,u12_1,u15_0)	6,000	48,000
C24000 1 mm Lead screw pitch and half-step mode (u4_248, u12_1, u15_1)	24,000	192,000

A<n> Move Plunger to Absolute Position

The [A] command moves the plunger to the absolute position <n>.

C3000<n>	0...3000	non-micro-step mode
<n>	0...24000	micro-step mode

C24000

<n>	0...24000	non-micro-step mode
<n>	0...192000	micro-step mode
(0)		default argument

For example:
[A300R] moves the syringe plunger to position 300
[A600R] moves the syringe plunger to position 600

a<n> Move Plunger to Absolute Position (Not Busy)

This is the same as the [A] command, except the status bit within the reply string, and any subsequent Query [Q] commands, indicates that the pump is not busy.

P<n> Relative Pickup

The [P] command moves the plunger down the number of steps <n> commanded. The new absolute position is the previous position plus <n>.

C3000

<n>	0...3000	non-micro-step mode
<n>	0...24000	micro-step mode
(0)		default argument

C24000

<n>	0...24000	non-micro-step mode
<n>	0...192000	micro-step mode

For example:

The syringe plunger is at position 0. [P300] moves the plunger down 300 steps. A subsequent [P600] command moves the plunger down additional 600 steps to an absolute position of 900.

The [P] command will return an Invalid Operand error if the final plunger position is greater than 3000 (24000 in micro-step mode).

p<n> Relative Pickup (Not Busy)

This is the same as the [P] command, except that the status bit of the reply string, and any subsequent Query [Q] commands, indicates that the pump is not busy.

D<n> Relative Dispense

The [D] command moves the plunger upward the number of steps <n> commanded. The new absolute position in the previous position - <n>.

C3000

<n>	0...3000	non-micro-step mode
<n>	0...24000	micro-step mode
(0)		default argument

C24000

<n>	0...24000	non-micro-step mode
<n>	0...192000	micro-step mode

For example:

The syringe plunger is at position 3000. [D300] will move the plunger up 300 steps to an absolute position of 2700.

The [D] command will return Invalid Operand error if the final plunger position will be less than 0.

d<n> Relative Dispense (Not Busy)

This is the same as the [D] command, except that the status bit of the reply string, and any subsequent Query [Q] commands, indicates that the pump is not busy.

Set Commands

Set Commands are used to configure the pump for specific operations. Plunger velocity and acceleration, motor current and Micro Stepping mode

Velocity and Acceleration Set Commands

Velocity and Acceleration Set commands are used to control the speed of the plunger. Plunger movement is structured into three phases:

- **Ramping Up**. Plunger movement begins with the start velocity and accelerates with the programmed slope to the constant or top speed.

- **Constant or Top Speed.** The plunger moves at the constant or top speed. Plunger speed or velocity can be programmed in Hz (half-steps/second) or in preprogrammed Set Speeds [S]. The actual time the plunger travels it dependent on the ramping up and down. If the plunger move is short, it may never reach top speed.

- **Ramping Down.** The plunger will decelerate based on the programmed slope. To enhance fluid break-off, the Cutoff command [c] can be used to define the end velocity of the plunger just before it stops.

For each plunger move, the firmware calculates how many steps the plunger must travel during each phase in order to move the total number of steps commanded.

The top velocity can be changed on the fly (while the plunger is moving) using the [V] command. When the move completes, the speed value reverts back to its original values.

In velocity/acceleration microstep mode ([N]<2>) Velocity and acceleration settings are set and reported in micro-steps /Sec. Otherwise they are reported in half-step/Sec.

Difference between C24000 and C3000 velocity settings

Since the C24000 has a 4 times finer lead screw pitch, the linear velocity is correspondingly 4 times slower for the same velocity settings.

NOTE: The argument for any of the velocity commands are the rotary speed of the motor in half-steps/Sec.

Thus, to aspirate/dispense at the same mL/sec rate, the velocity command (“V”) needs to be multiplied by 4 with the C24000. For example V1000 in the C3000 is equivalent to V4000 in the C24000. This same logic applies to the other Velocity/Acceleration commands.

L<n> Set Acceleration Slope

During the beginning and end of a move, the plunger speed ramps up and down respectively. The ramp is programmed using the Set Slope [L] command. It is calculated as <n> x 2.5 kHz/sec. The syntax for this command is:

<n> 1... 20 Hz = half-step/Sec
<n> 8... 160 micro-step [N]<2> mode, Hz = micro-steps/Sec
{14} Power up default

The corresponding slopes in kHz/sec are listed below:

Slope Code	KHZ/SEC
1	2.5
2	5.0
3	7.5
4	10.0
5	12.5
6	15.0
7	17.5
8	20.0
9	22.5
10	25.0
11	27.5
12	30.0
13	32.5
14	35.0
15	37.5
16	40.0
17	42.5
18	45.0
19	47.5
20	50.0

v<n> Set Start Velocity

The [v] command sets the velocity at which the plunger begins its movement. The plunger will then ramp up (slope) to the top velocity. The start velocity [v] normally should always be less than the top velocity [V]. If not, the plunger will decelerate to its start velocity [v] to its top velocity [V]. The syntax for this command is:

<n> 1...1000
<n> 1...8000 micro-step [N]<2> mode, Hz = micro-step/Sec
{900} Power up default

V<n> Set Top Velocity

The [V] command sets the top speed in Hz (half-steps/second). The syntax for this command is:

<n> 1...6000 Hz = half-step/Sec
<n> 1...48000 micro-step [N]<2> mode, Hz = micro-step/Sec
{1400} Power up default,C3000
{5600} Power up default,C24000

The top velocity can be changed on the fly, that is while the plunger is moving, using the [V] command. When the move completes, the speed value reverts back to its original value. Thus, on the fly velocity changes only affect the current move.

“On the Fly” velocity changes are limited to a maximum 2000. Any request changes greater than 2000 will result in an Invalid Operand error. Also, the Cutoff velocity[c] is set equal to the top velocity [V]. Thus, there is no deceleration for that move.

If the cutoff velocity [c] is higher than the desired top velocity [V], the cutoff velocity [c] is changed to equal the top velocity [V].

NOTE: The [c] cutoff velocity will not revert back to its original value if the top velocity [V] is changed back.

S<n> Set Speed

The [S] command sets the top velocity [V] to predefined speed codes shown in the table below.

<n> 0...40
{11} Power up default

These speeds do not cover the full range of speeds the plunger can travel. They are commonly used velocities provided for the convenience of the user.

The [S] command sets top velocity [V] without changing start velocity [v], slope [L] and cutoff velocity [c] except under the following condition:

If the cutoff velocity [c] is higher than the desired top velocity [V], the cutoff velocity [c] is changed to equal the top velocity [V].

NOTE: The [c] cutoff velocity will not revert back to its original value if the top velocity [V] is changed back.

Speed Code [S<n>]	Syringe Top Velocity [V] (half-steps/sec N = 0 or N = 1 mode or micro-step/sec N = 2 mode)
0	6,000
1	5,600
2	5,000
3	4,400
4	3,800
5	3,200
6	2,600
7	2,200
8	2,000
9	1,800
10	1,600
11	1,400
12	1,200
13	1,000
14	800
15	600
16	400
17	200
18	190
19	180

S<n> Set Speed Continued

Speed Code [S<n>]	Syringe Top Velocity [V] (half-steps/sec N = 0 or N = 1 mode or micro-step/sec N = 2 mode)
20	170
21	160
22	150
23	140
24	130
25	120
26	110
27	100
28	90
29	80
30	70
31	60
32	50
33	40
34	30
35	20
36	18
37	16
38	14
39	12
40	10

c<n> Set Cutoff velocity in Hz

The [c] command sets the cutoff velocity. The cutoff velocity is the velocity at which the plunger ends its movement. The plunger will slope down [L] from the top velocity [V]. The [c] command overwrites the [C] command.

<n> 1 ...2700
<n> 1 ...21600 micro-step [N]<2> mode, Hz = micro-step/Sec
{900} Power up default

The cutoff velocity [c] must be less than or equal to the top velocity [V]. If an attempt is made to set the cutoff velocity [c] less than the top velocity [V], the [c] cutoff velocity will be set equal to the top velocity [V].

C<n> Set Cutoff velocity in steps

During the last phase of a plunger move, the speed ramps down (as defined by the programmed slope) toward the cutoff velocity [c]. When the cutoff steps [C] are specified, the plunger stops at <n> steps before reaching the cutoff velocity. The total number of steps required by the plunger movement is maintained by adding <n> steps to the second phase (top velocity) of the plunger move.

<n> 0...25 steps
{0} Power up default

For example, [C5] stops the plunger five steps short of the final velocity. The total number of steps is automatically maintained by adding five steps to the second phase of plunger movement. In other words, the deceleration phase of the move is shortened by five steps and the constant speed phase is lengthened by five steps.

K<n> Backlash steps

The [K] command sets the number of backlash steps <n>.

<n> 0...100
{10} Power up default C3000
{80} Power up default C24000

When the syringe drive motor reverses direction, the plunger arm will not move until the backlash due to mechanical play within the system is compensated. To provide this compensation, during aspiration, the plunger moves down additional steps, then backs up the set number of backlash steps. This ensures that the plunger is in the correct position to begin a dispense move. Note that a small volume of fluid flows out the Input side of the valve during this operation.

N<n> Microstep Positioning and Velocity Mode

The [N] command enables or disables micro-stepping mode. In micro-step position mode, plunger resolution is 8 times greater than normal or non-micro-step mode. In micro-step velocity mode, all velocity and acceleration parameters are set and reported in micro-steps

This command also allows for velocity parameters [v], [V], [c] and [L] to be set and reported in micro-step/sec units. This mode allows for finer control of the velocity settings. Please note that by changing between [N] =0 or [N] =1 mode and [N] = 2 mode, the existing velocity and acceleration settings are not automatically scaled to keep the same velocity. Thus, going to [N] = 2, without changing the Velocity/Acceleration settings, will cause the plunger to move 8 times slower. Also note that by going to [N] = 2 mode to [N] = 1 or [N] = 0 mode, without changing the Velocity/Acceleration settings, can result in settings that are not advisable.

<n> 0...2
{0} Power up default, half-step mode

<n>	Description
0	**Normal mode**: Plunger position is set and reported in half-steps All velocity settings are in half-steps/sec Stroke is 3000 half-steps/full stroke
1	**Micro-step position mode**: Plunger position is set and reported in micro-steps Velocity settings are set and reported in half-steps/sec Stroke, for the C3000, is 8 * 3000 = 24000 micro-steps/full stroke Stroke, for the C24000, is 8 * 24000 = 192,000 micro-steps/full stroke
2	**Micro-step position and velocity/acceleration mode**: Plunger position is set and reported in micro-steps Velocity and acceleration settings are set and reported in micro-steps/sec Stroke, for the C3000, is 8 * 3000 = 24000 micro-steps/full stroke Stroke, for the C24000, is 8 * 24000 = 192,000 micro-steps/full stroke

h<n> Set Syringe Motor Holding current

Sets the syringe's motor hold, or non-moving, current to the <value > specified in percent of maximum. On power up, this value will be overwritten to the factory set default value.

<n> 0…100 % of maximum current
{10} Power up default set at factory

m<n> Set Syringe Motor Run current

Sets the syringe motor run, or moving current, to the <value> specified <n> in percent of maximum. On power up, this value will be overwritten to the factory set default value.

<n> 0…100 % of maximum current
{75} Power up default set at factory

J<n> Auxiliary Outputs

The [J] command sets the three auxiliary TTL output lines.

The syntax for this command is:

<n> 0...7
{0} Power up default

The C-Series provides three TTL outputs on connector JP3 (pins 13, 14, 15) that correspond to outputs 1, 2, and 3. They are controlled as follows:

Command	Output 3 (pin 15)	Output 2 (pin 14)	Output 1 (pin 13)
J0	0	0	0
J1	0	0	1
J2	0	1	0
J3	0	1	1
J4	1	0	0
J5	1	0	1
J6	1	1	0
J7	1	1	1

(0 = low, Gnd; 1 = high, +5VDC)

j<ppppn> Set Auxiliary Outputs based on syringe position

The [j] command sets the three auxiliary TTL output lines to the specified state <n> when the actual syringe position is less than or equal to the specified syringe position

The syntax for this command is:

<pppp> 1-3000 Position value where Aux outputs will be set when the syringe position is less than or equal to this value
<n> 0...7, Sets TTL Output state , argument works the same as the [J] command

Normally this command is used during a dispense operation to provide an early trigger to another pump. This allows for continuos dispense flow with multiple pumps.
For example, using the following string:

[J0IA3000j5007A0GR]

J0 - Set all 3 auxiliary outputs low
I - Valve to Input position
A3000 - Aspirate, Move syringe down to bottom of stroke
j5007 - Set all 3 outputs high when syringe position is less than or equal to 500
O - Move Valve to Output
A0 - Dispense, Move syringe up to top of stroke, outputs will change state when syringe position is less than or equal to 500
G - Repeat forever
R - Execute command string

i<n> Control the optional +24V solenoid output

i<n>	Solenoid state
i or i0	de-energized
i1	energized

Control Commands

R Execute command or Program String

The [R] command tells the pump to execute a new or previously loaded but unexecuted command string. This command will also cause the resumption of a halted [H] command string.

Commands containing [R] at the end of the string will execute immediately. If the command or program string is sent without the [R], it is placed in the command buffer.

Sending the [R] alone will execute the last unexecuted command in the buffer. Sending another [R] will not repeat the program string that has previously been executed.

X Execute the Last Command of Program String

Repeats the last executed command string. Note that strings that contain looping commands, [g] and [G], are not valid when using [X].

G<n> Repeat command Sequence

This command repeats a command or program string the specified number of times. With a [GR] or a [G0R], the sequence is repeated indefinitely or until a [T] terminate command is issued. The [G] command can be used to nest up to 10 loops and can be repeated up to 30,000 times.

<n>	0...30000	# of times to repeat
(0)		Default argument, repeats indefinitely

Note that the argument <0> is a special case. It causes the loop to repeat indefinitely.

For example:

[A3000A0G10R] moves the syringe plunger to position 3000 then back to position 0. This sequence is repeated 10 times.

g Mark the Start of a Repeat Sequence

The [g] command is used in conjunction with the [G] command. The [g] command marks the beginning of a repeat sequence (loop) that occurs within program string (i.e., the entire string is not repeated). Both the [g] and [G] commands can be used to nest up to 10 loops.

An example of command nesting is shown below with the following string:

[A0gP50gP100D100G10G5R]

A0	-	Move plunger to position 0
g	-	Outer loop start
P50	-	Move plunger down 50 steps
g	-	Inner loop start
P100	-	Move plunger down 100 steps
D100	-	Move plunger up 100 steps
G10	-	Go to Inner loop start, repeat 10 times
G5	-	Go to Outer loop start, repeat 5 times
R	-	Execute command string

M<n> Delay Command Execution

The [M] command delays execution of a command in milliseconds. This command is typically used to allow time for liquid in the syringe and tubing to stop oscillating thereby enhancing precision. The syntax for this command is:

<n> 0...30000 milliseconds

H<n> Halt Command Execution

<n> 0...2
(0) Default argument

The [H] command is used within a program string to halt execution of the string. To resume execution, a [R] command or TTL signal must be sent. Two TTL inputs are available, Input 1 (JP3 pin 7), and Input 2 (JP3 pin 8). Also note that both inputs are pulled up to +5V.The status of the TTL input lines can be read using [?13] and [?14]. How the H Command reacts to the TTL inputs can be configured using the EEPROM u16 command. See details below.

Halt Command execution is as follows:
<n> = 0 Waits for [R] or Low signal on either Input 1 or 2
<n> = 1 Waits for [R] or Low signal on Input 1
<n> = 2 Waits for [R] or Low signal on Input 2
Note the default configuration is that the inputs are level sensitive. That is, after the [H] command, if the respective Input is low, operation will continue. The input does not need to transition from High to Low.

EEPROM u16_X, where X<=50. Default for this parameter is 0.Units are in mS. After the [H] command, the respective Input must be High continuously for at least X milliseconds before a Low transition will be recognized. Upon transition from High to Low, the falling edge, the input must remain Low continuously for X milliseconds before the string will resume operation. The auxiliary input de-bounce only functions if a specific input is selected. That is, it is only valid using [H]<1> or H<2>. It has no effect if using [H]<0>.

For example, the following command string is sent:

[ZgH1IA1000H2OA0G0R]

The pump initializes, waits for the trigger, or low signal on Input 1 then aspirates 1000 steps. It then waits for a low on Input 2 before dispensing:

Z Initialize pump
g Start loop
H1 Wait for low on Input1
I Valve to Input position (Aspirate)
A1000 Move syringe to position 1000
H2 Wait for low on Input2
O Valve to Output position (Dispense)
A0 Move syringe to position 0
G0 Loop back to [g], run forever
R Run

T Terminate Command

The [T] command immediately terminates any executing command string. All plunger or valve movements are terminated immediately.

x Execute next Command in buffer based on Aux inputs

Execute the next command in the string based on the Auxiliary inputs.

<n> 0...3

<arg>	Input2	Input1	Action
<0>	Low	Low	Will execute next command in the string buffer if Input2 and Input1 are held Low
<1>	Low	High	Will execute next command in the string buffer if Input2 and Input1 are set as indicated
<2>	High	Low	Will execute next command in the string buffer if Input2 and Input1 are set as indicated
<3>	High	High	Will execute next command in the string buffer if Input2 and Input1 are both High

Input 1 is located on connector JP3 pin 7, and Input 2 on JP3 pin 8.

NOTE: Auxiliary inputs are internally pulled High. Thus, if left floating, they will be High.

The [x] command in conjunction with the [e] command can be used as an IF..ELSE, IF..ELSE statement based on the auxiliary TTL inputs. This is especially useful in stand-alone operation.

For example:

The example below allows the C-Series in stand alone mode to switch between three modes of operation depending on the states of Input 1 and Input 2. The C-Series is configured to Auto Run String 0 on power up.

If Input 2 is Low and Input 1 is High, [e1] will be executed. Thus, the pump will Aspirate/ Dispense cycle 50 steps.

If Input 2 is High and Input 1 is Low, [e2] will be executed. Thus, the pump will Aspirate/ Dispense cycle 1000 steps.

If none of the above states of Input 2 and Input 1 are realized, then [e3] will be executed. Thus, the pump will Aspirate/Dispense cycle the full stroke of 3000 steps.

The following four strings are programmed into the EEPROM locations 0, 1, 2 and 3.

[s0Zx1e1x2e2e3R]
[s1gIA50OA0G0R]
[s2gIA1000OA0G0R]
[s3gIA3000OA0G0R]

String 0 [e0]

s0 Store following in EEPROM location 0 (executed on power up)
Z Initialize Pump
x1 Execute next instruction if Input 2 is tied Low and Input 1 is High (or left open)
e1 Jump to String 1
x2 Execute next instruction if Input 2 is High (or left open) and Input 1 is tied Low
e2 Jump to String 2
e3 Else, jump to String 3
R Run.

String 1 [e1]

s1 Store following in EEPROM location 1
g Start loop
I Valve to Input position (Aspirate)
A50 Move syringe to position 50
O Valve to Output position (Dispense)
A0 Move syringe to position 0
G0 Loop back to [g], run forever
R Run

String 2 [e2]

s2 Store following in EEPROM location 2
g Start loop
I Valve to Input position (Aspirate)
A1000 Move syringe to position 1000
O Valve to Output position (Dispense)
A0 Move syringe to position 0
G0 Loop back to [g], run forever
R Run

String 3 [e3]

s3 Store following in EEPROM location 3
g Start loop
I Valve to Input position (Aspirate)
A3000 Move syringe full stroke to position 3000
O Valve to Output position (Dispense)
A0 Move syringe to position 0
G0 Loop back to [g], run forever
R Run

NOTE: Using the [e] command in a string will force a jump to the specified string, it will not return to the departure point once the “jumped to” string has completed.

Non-Volatile Memory (EEPROM) commands

The non-volatile memory in the C-Series can store up to 14 separate program strings. Thus providing the user with the option of computer-free stand-alone operation. The pump can be programmed to run stored programs using the [s] command.

On power up, if the Auto Run jumper is installed on the back of the pump, the string corresponding to the rotary switch position will be automatically executed.

For example:

The following 2 strings are programmed into location 0 and 1:
[s0ZIP1000H0OD1000R]
[s1ZP500H0OD500R]

The Auto Run jumper is installed on the back of the pump.
If the rotary switch on the back of the pump is set to 0, [s0] will run automatically. If the rotary switch is set to 1, [s1] will run automatically.

s<n> Load Program String into Non-Volatile Memory

The non-volatile memory in the C-Series can store a program string thus providing the user with the option of computer-free operation. The [s] command is placed at the beginning of a program string to load the string into the non-volatile memory.

<n> 0...14

Up to 15 program strings (numbered 0 through 14) can be loaded into the non-volatile memory. Each string can use up to 128 characters. For example, [IA3000OA0R] requires 10 characters

To run a stored string automatically on power up, the auto run jumper must be installed and the rotary address switch set to the proper address. The table below shows the relationship between the stored strings [s<n>] and the rotary switch.

Rotary Switch setting	**String referenced**
0	s0
1	s1
2	s2
3	s3
4	s4
5	s5
6	s6
7	s7
8	s8
9	s9
A	s10
B	s11
C	s12
D	s13
E	s14

The [e]<n>] command can also be used to execute the string.

NOTE: An Initialization command should always be included in the non-volatile memory command string if the pump will be used in standalone mode.

Example program string: [s8ZS1gIA30000H0OA0GR]

Command Segment	Description
s8	Loads string into the program 8 of non-volatile memory (Address switch position 8)
Z	Initializes pump
S1	Sets plunger speed
g	Marks start of loop
I	Turns valve to Input position
A3000	Moves plunger to position 3000
H0	Halt operation until either TTL inputs go Low
O	Turns valve to Output position
A0	Moves plunger to position 0
G	Go to [g], repeat indefinitely
R	Executes command string

e<n> Execute non-volatile memory program string

Execute EEPROM string stored at location <n>.

<n> 0...14

For example:

[e8R] will run the string stored in EEPROM location 8.

Linking Program Strings in the Non-Volatile memory

Non-volatile memory program strings can be linked by ending one program string with an [e] command that refers to a second program string.

Example program strings: [sIZgIA3000OA0G5e2R]
[s2gIA3000OgH0D300G10GR]

The first string loads an initialization and prime sequence into program 1 of the non-volatile memory (address switch position 1). It then links to string 2 in the non-volatile memory.

The second string loads an aspirate and dispense sequence into program 2 of the non-volatile memory. The second non-volatile memory program string fills the syringe, then performs 10 dispenses of 300 steps each.
Due to the [H0], the dispenses are triggered by the proper auxiliary input, or a [R] command. This sequence is repeated endlessly until the pump is powered down.

If the Auto Run jumper is installed and the address switch is set correctly, on power-up, the pump will automatically initialize, prime and perform the multiple dispenses until it is again powered down.

NOTE: When linking program strings, a jumped to string will not return to the calling string. In the example above: [s1] jumps to [e2]. Once [e2] has executed, control will **not** return to the calling sting [s1]. Thus, [e] commands are normally placed at the end of a string just before the [R].

u<n_xxx> **Set Pump Configuration EEPROM Parameters**
For factory use only.

Will load pump configuration and calibration info into the internal EEPROM. Some of these parameters can also be changed with the user friendly [U] command. Note, these parameters are only read on power up. Thus they will only take effect when the power is cycled. Note this command, unlike the other Set commands, does not require and [R] to execute.

Command	Description	C3000 Factory Default	C24000 Factory Default
u1_XXX	Motor hold current, 0–100%	10	10
u2_XXX	Motor run current, 0–100%	75	50
u3_XXX	Default V max and initialization speed in 100 half-steps/sec increments (1-60)	14	56
u4_XXX	Plunger stroke in half-steps * 100	62	248
u5_X	0 = Don't auto initialize valve 1 = Automatically initialize valve on power up 2 = No valve circuitry installed on PCB	1	1
u6_X	CAN Baud rate 0 = CAN Buss disabled 1 = 100K 2 = 125K 3 = 250K 4 = 500k 5 = 1M	1	1
u7_XX	Power up default backlash in half-steps, [K] command	20	80
u8_X	Number of steps to jam or stall the plunger into the top of the syringe during plunger initialization.	10	10
u9_XXX	Power up default dead volume in half-steps, [k] command	48	384
u10_IOB	3 way valve position I = Input valve position (0-2) Position 0 = 0 deg, Position 1 = 120 deg, Position 2 = 240 deg O = Output valve position (0-2) B = Bypass valve position (0-2)	210	210

Table continued on next page.

u<n_xxx> Set Pump Configuration EEPROM Parameters Continued

Command	Description	C3000 Factory Default	C24000 Factory Default
u11_ IOBEXYZ	4 way valve position I = Input valve position (0-3) Position 0 = 0 deg, Position 1 = 90 deg, Position 2 = 180 deg, Position 3 = 270 deg O = Output valve position (0-3) B = Bypass valve position (0-3) E = Extra valve position (0-3) X Allow plunger movement while valve is in Bypass position X = 1, allow movement, X = 0, don't allow movement Y Allow plunger movement while valve is in Extra position Y = 1, allow movement, Y = 0, don't allow movement Z Swap the Bypass and Extra position on a 4 position valve if a Y init command is issued Z = 1, Swap Z = 0, Don't Swap	2130001	2130001
u12_X	X = 1, Half-step syringe motor resolution X = 0, Full step resolution Note: In half-step mode, stroke = 6000 or 48000 in micro-step mode.	0	1
u13_X	X = 1, AutoRun Mode X = 0, Regular mode Note: This setting performs the same function as the Auto-Run jumper on the back of the pump. If the Auto-run jumper is installed, it will override the EEPROM setting.	0	0
u14_X	X = Number of ports on a distribution valve X = 0, Non distribution valve	0	0
u15_X	X = 0, standard lead screw pitch X = 1, 1 mm lead screw pitch, 4X step resolution X = 2, 2 mm lead screw pitch, 2X step resolution	0	1
u16_X	De-bounce delay for trigger inputs in mS. Valid arguments are 1-50. After the [H] command, the respective Input must be High for at least X milliseconds before a Low transition will be recognized. Upon transition from High to Low, the falling edge, the Input must remain Low for X milliseconds before the string will resume operation. Only valid for [H]<1> or [H]<2>. Not valid for [H]<0>	0	0
u17_XX	Default init current in percent for full force initialization	25	30
u18_XX	Default init current in percent for medium force initialization	20	25
u19_XX	Default init current in percent for low force initialization	15	20
u20_XXXXXXX	X = 7, character alpha-numeric internal TCS catalog number		

n<x> Calibrate encoder levels and store in EEPROM

For factory use only.

Encoder voltage output levels can calibrated and set into the EEPROM
This command will run the pump through the calibration process, calculate the values, and store them into EEPROM. These values can be read back using the '?21" report command

U<n> Set Pump Configuration EEPROM Parameters

Note, these parameters are only read on power up. Thus they will only take effect when the power is cycled. Note this command, unlike the other Set commands, does not require and [R] to execute.

Argument <n>	Description
0	Reserved for future use.
1	3-port Y vlve. Note: Valve selection jumper on the back of the pump must also be installed
2	4-port. Note: Valve selection jumper on the back of the pump must also be removed.
3	Reserved for future use.
4	4-port distribution valve that uses [I], [O], [B] and [E] commands. Refer to figure 4.
5	T-valve.
7	Reserved for future use.
8	Reserved for future use.
9	Reserved for future use.
11	4-port distribution valves that use [I]<n> and [O]<n>. Note: In this configuration, Valve selection jumper on the back of the pump is ignored. Refer to figure 5.
30	Set Auto Run mode. Note: This setting performs the same function as the Auto-run jumper on the back of the pump. Note: If the Auto-run jumper is installed, it will override the EEPROM setting.
31	Clear Auto Run mode. Note: If the Auto-run jumper is installed, it will override the EEPROM setting.
41	Reserved for future use.
47	Reserved for future use.
51	Set CAN baud rate to 100K.
52	Set CAN baud rate to 250K.
53	Set CAN baud rate to 500K.
54	Set CAN baud rate to 1Meg.
57	Set CAN baud rate to 125K.

f<i>,<xx> Set custom motor step table

For factory use only.

<i> 0...63
<n> 0.255

To read back programmed values, use ?46 and ?47. To run this table, use [t]<4>.

Non-Functional Commands

The following commands have been included in the C-Series command set to make the pump backward compatible with other pumps. These commands are non-functional.

^<n> Set Threshold Value for Fluid Detection

Always returns 255.

b Clear run from non-volatile memory

Report Commands

Report commands report various pump parameters. The response is returned immediately and can be used when the pump is busy executing another command string.

Report commands do not require a [R] command.

? or RZ Report Absolute Plunger Position

Reports the absolute position of the plunger in steps (0…3000), [0…24000 in micro-step mode].

?1 Report Start Velocity

Reports the start velocity [v] in Hz [1…1000].

?2 Report Top Velocity

Reports the set top velocity [V] in Hz [1...6000].

?3 Report Cutoff Velocity

Reports the cutoff velocity [c] in Hz [1...2700].

?4 or ?5 Report Absolute Plunger Position

Same as ?

?6 Report Valve Position

Reports the valve position in mnemonics (i = input, o = output, b = bypass and e = extra). If a distribution valve is selected, returns the port number 1...X, where X is the number of ports

?7 Report Acceleration Slope

Reports the acceleration slope set using the [L] command

?10 or F Report Command Buffer Status

Reports the command buffer status. If the buffer is empty, the pump returns status code 0. If the buffer is not empty, the pump returns a 1. If a program string is sent to the pump without a [R] command, the string is loaded into the buffer and the buffer status becomes 1. A [R] command will then execute the command stored in the buffer.

0 = empty
1 = commands in buffer

?12 Report Number of Backlash Steps

Reports the backlash steps [K]

?13 Report Status of Auxiliary Input #1 (JP3, Pin 7)

0 = Low
1 = High

?14 Report Status of Auxiliary Input #2 (JP3, Pin 8)

0 = Low
1 = High

?15 Non-functional

Always reports 1

?16 Non-functional

Always reports 1

?17 Non-functional

Always reports 1

?18 or % Report Number of Valve Movements (since last report)

Reports the number of valve movements since the last [?18] or [%] command.

?19 Report if Pump ahs been initialized

0 = not initialized
1 = initialized

?20 or # Report Firmware Checksum

Reports back the firmware checksum.

?21 Report calibrate Encoder levels

Reports the calibrate encoder levels

?22 Non-functional

Always reports 255.

?23, &, or RV Report Firmware Version

Reports the firmware version. Format is "C3000: MMDDYY".

NOTE: C3000 is the response regardless of whether the actual pump is a C3000 or C24000 configuration
MM = month
DD = day
YY = year

?24 Report the Dead Volume

Reports Dead Volume [k].

?25 Motor Hold Current

Reports the syringe motor holding current [h] in %.

?26 Motor Run Current

Reports the syringe motor running current [m] in %.

?27 or ?76 Configuration EEPROM

Reports the confirmation EEPROM data set by the [u] command.

?28 Valve Jumper State

Reports the state of the 3 or 4 position valve jumper.
3 = 3 position valve, jumper installed.
4 = 4 position valve, jumper not installed.

?29 or Q Report System Status

Reports error codes and pump status (Idle or Busy)

?30 - ?44 Reports user programmed EEPROM strings.

[?30] reports [s0] string
[?31] reports [s1] string
[?32] reports [s2] string
[?33] reports [s3] string
[?34] reports [s4] string
[?35] reports [s5] string
[?36] reports [s6] string
[?37] reports [s7] string
[?38] reports [s8] string
[?39] reports [s9] string
[?40] reports [s10] string
[?41] reports [s11] string
[?42] reports [s12] string
[?43] reports [s13] string
[?44] reports [s14] string

?45 Optional solenoid report command
0 = solenoid de-energized
1 = solenoid energized

?46 User set motor sine table, first 32 bytes

?47 User set motor sine table, last 32 bytes

C-Series Status and Error Codes

The [Q] command reports error codes and pump status (Idle or Busy). The user should send a [Q] command before sending a program string or individual command to ensure that the pump has completed the previous command successfully.

The response to the [Q] command (the status byte) provides two items of information: Pump status (bit 5) and error code (bits 0-3).

Status Bit

Bit 5 is the status bit. It indicates when the pump is busy or not busy. The designations for bit 5 are listed below.

Status Bit 5	Description
X = 1	Pump is Idle. It is ready to accept new commands
X = 0	Pump is Busy and will only accept Report, Terminate (T) or (V) commands.

In response to uppercase Move commands ([A], [P] and [D]), the [Q] command reports that the pump is Busy. In response to lowercase Move commands ([a], [p], and [d]), the [Q] command reports that the pump is Idle. Additionally, commands addressed to multiple pumps at once cannot be used to obtain pump status; each pump must be queried separately.

NOTE: Although the answer block for other commands contains a status bit, it should not be used for determining pump status. A [Q] command is the only valid method to determine if the pump is busy. The error information in the status byte of the answer block is always valid.

Error Codes

Error codes describe problem conditions that may be detected in the C-Series. Error codes are returned in the least significant four bits of status byte. If an error occurs, the pump stops executing commands, clears the command buffer, and inserts the error code into the status byte. Some errors continue to appear, such as Plunger Overloads, until they are cleared by the Initialization command. On a Plunger Overload, the device will not execute another plunger Move command until it is reinitialized.
The last error has precedence in the status byte. For example, if a Command Overflow occurs, an error 15 results. If the next command causes an error #3, the status byte reflects the error #3 (Invalid Operand).

Table 7. C-Series Error Codes

Error Code	Status Byte if Idle (ACSII)	Status Byte if Busy (ASCII)	Description
0 (00h)	`	@	**Error Free.** Condition
1 (01h)	a	A	**Initialization error.** This error occurs when the pump fails to initialize. Check for blockages and loose connections before attempting to reinitialize. The pump will not accept commands until it has been successfully initialized. This error can only be cleared by successfully initializing the pump
2 (02h)	b	B	**Invalid Command.** This error occurs when an unrecognized command is issued. Correct the command and operation will continue normally.
3 (03h)	c	C	**Invalid Operand**. This error occurs when an invalid parameter (<n>) is given with a command. Correct the parameter and pump operation will continue normally.
4 (04h)	d	D	**Invalid Checksum.** In OEM mode, the checksum did not match the received string
6 (06h)	f	F	**EEPROM Failure.** This error occurs when the EEPROM is faulty. If you receive this error, please call TriContinent Customer Service.
7 (07h)	g	G	**Device Not Initialized.** This error occurs when the pump is not initialized. To clear the error, initialize the pump.
8 (08h)	h	H	**CAN bus failure.**
9 (09h)	i	I	**Plunger Overload.** This error occurs when movement of the syringe plunger is blocked by excessive back pressure. The pump must be reinitialized before normal operation can resume. This error can only be cleared by reinitializing the pump
10 (0Ah)	j	J	**Valve Overload.** This error occurs when the valve drive loses steps by blockage or excess back pressure. The pump must be reinitialized before normal operation can resume. Sending another Valve command reinitializes the valve and sets it to the correct location. Continual valve overload errors could be an indication the valve should be replaced.
11 (0Bh)	k	K	**Plunger Move Not Allowed**. When the valve is in the bypass or throughput position, Plunger Movement commands are not allowed
15 (0Fh)	o	O	**Command Overflow.** This error occurs when the command buffer contains more than 255 characters. Commands in the buffer must be executed before more commands can be sent. A command overflow will also occur if the pump is busy executing a command and another command string is requested to run.

The pump handles errors differently depending on the error type. There are four error types, which are described below.

Immediate Errors

These include “Invalid Command” (error 2), “Invalid Operand” (error 3), “Invalid Checksum” (error 4), “Plunger Move Not Allowed” (error 11) and “Device not Initialized” (error 7). Any subsequent [Q] command will report the error. In certain cases, the answer block immediately returns an error.
There is no need to reinitialize the pump following this error type.

Initialization Errors

These include “Initialization error” (error 1) and “Device not Initialized” (error 7).

To ensure that the pump initialized successfully, send a [Q] command after the Initialization [Z], [Y] or [W] commands.

- If an error occurs during the initialization, an “Initialization error” (error 1) will be returned with the [Q]’s response. The pump must be reinitialized until the [Q} command indicates successful initialization.

- If the [Q] command indicates both a successful initialization and that the pump is ready, subsequent move commands can be sent.

- If Initialization is not successful, or if any move command is sent prior to an Initialization command, a “Device Not Initialized” error 7, is returned with any Plunger movement command

Overload Errors

These include the “Plunger Overload” and “Valve Overload’ errors (error 9 and 10). If the pump returns either of these errors, the pump must be reinitialized before continuing. If another Plunger or Valve movement command is sent without reinitializing the pump, the “Device not initialized” error will be returned.

Command Overflow Error

This error occurs when certain commands are sent to the pump while it is busy executing a previous command string. Any Move, Set (except [V]), or Valve commands that are sent while the pump is busy, will cause this error to be issued. The pump ignores the command and issues a Command Overflow error.
The [Q] command allows the controller to determine when the command is complete and the pump ready to accept new commands.
There is no need to re-initialize the pump following this error type.

Report commands, top velocity [V] and the terminate [T] command, will not return a Command Overflow error. These commands are considered valid even when the pump is Busy.

Table 8. Error Codes, Status Byte with ASCII and Hexadecimal Values

Status Byte	Hex if Status Bit 5 =		ASCII if Status Bit 5 =		Error Code	Description
7 6 5 4 3 2 1 0	**X= 0 (Busy)**	**X=1 (Idle)**	**X= 0 (Busy)**	**X=1 (Idle)**	**Number**	**Error**
0 1 X 0 0 0 0 0	40h	60h	@	`	0	No Error
0 1 X 0 0 0 0 1	41h	61h	A	a	1	Initialization failure
0 1 X 0 0 0 1 0	42h	62h	B	b	2	Invalid Command
0 1 X 0 0 0 1 1	43h	63h	C	c	3	Invalid Operand
0 1 X 0 0 1 0 0	44h	64h	D	d	4	Invalid Checksum,(OEM mode)
0 1 X 0 0 1 0 1	45h	65h	E	e	5	Unused
0 1 X 0 0 1 1 0	46h	66h	F	f	6	EEPROM Failure
0 1 X 0 0 1 1 1	47h	67h	G	g	7	Device not Initialized
0 1 X 0 1 0 0 0	48h	68h	H	h	8	CAN bus failure
0 1 X 0 1 0 0 1	49h	69h	I	i	9	Plunger Overload
0 1 X 0 1 0 1 0	4Ah	6Ah	J	j	10	Valve Overload
0 1 X 0 1 0 1 1	4Bh	6Bh	K	k	11	Plunger Move Not Allowed
0 1 X 0 1 1 1 1	4Fh	6Fh	O	o	15	Command Overflow

Error Reporting Examples

[A4000R] Since <4000> is greater than the stroke of the C-Series, this returns an error immediately in the command response. When queried ([Q] command), does not return error.

[A3000P3500R] Moves to position 3000 then stops. The [P3500] is past the stroke of the C-Series, a [Q] command returns an error.

[e200R] <14> is the maximum argument for [e]. Returns an invalid command error immediately in the command response. The pump status is Idle.

[A3000e2000R] Returns an invalid command error immediately in the command response. The pump is Idle.

[BA1000R] Since valve is in the bypass position, plunger movements are not allowed. This will returns an error immediately. When queried with the [Q] command does not return an error.

Figure 6. C-Series Diagnostic LEDs

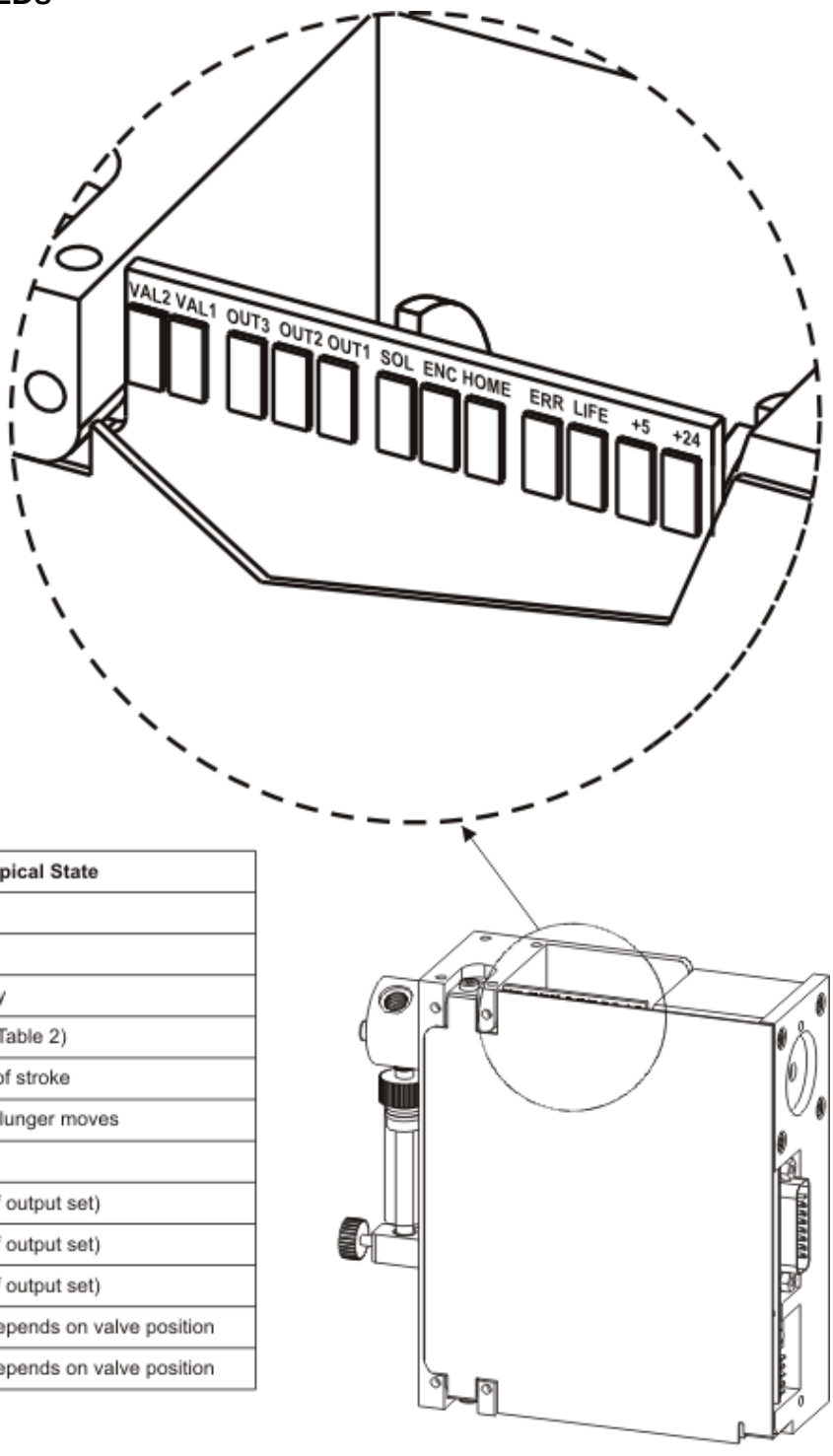


Table 1

LED	Function	Normal/Typical State
+24	24 VDC Supply	ON
+5	5 VDC Regulator	ON
LIFE	Processor Heartbeat	Blink slowly
ERR	Error	OFF (See Table 2)
HOME	Top of stroke sensor	ON at top of stroke
ENC	Linear encoder sensor	Blinks as plunger moves
SOL	Solenoid output	ON
OUT1	Auxiliary output 1	ON (OFF if output set)
OUT2	Auxiliary output 2	ON (OFF if output set)
OUT3	Auxiliary output 3	ON (OFF if output set)
VAL1	Valve sensor	ON/OFF depends on valve position
VAL2	Valve sensor	ON/OFF depends on valve position

Table 2

ERR LED	Error
OFF	No error
1 Blink	Initialization error
2 Blinks	EEPROM failure
3 Blinks	Plunger overload
4 Blinks	Valve overload

C-Series RS232 Command Summary

Command	Operand range <n>* ( ) = microstep mode limits	Default Operand	Power up default	Command Description	Operand description
Control Commands					
R	N/A	N/A		Execute command string	
x	0...3	N/A		Execute next command in buffer based on auxiliary inputs	<0> = Execute if Input2 is Low and Input1 is Low <1> = Execute if Input2 is Low and Input1 is High <2> = Execute if Input2 is High and Input1 is Low <3> = Execute if Input2 is High and Input1 is High
X	N/A	N/A		Re-execute last executed command string	
G<n>	0...30000	0		Repeat command sequence	0 = Loop forever
g	N/A	N/A		Mark the start of a repeat sequence	
M<n>	0...30000			Delay command execution	Milliseconds
H<n>	0-2	0		Halt command execution	<0> = Wait for [R] or either input 1 or 2 to go low <1> = Wait for [R] or input 1 to go low <2> = Wait for [R] or input 2 to go low
T	N/A	N/A		Terminate command	
Initialization Commands					
Z<n>	0...40	0		Initialize plunger, valve to the right	<0> = initialize at full plunger force <1> = initialize at low plunger force <2> = initialize at lower plunger force <3> = initialize at speed 16, low plunger force <4> = initialize at speed 18, low plunger force <5-9> = same as <0> <10-40> = initialize at defined plunger speed
Y<n>	0...40	0		Initialize plunger, valve to the left	Same as Z<n>
W<n>	0...40	0		Initialize plunger without valve	Same as Z<n>
z<n>	0...3000 (0...24000)	0		Set pump's internal position counter to value specified	
k<n>	0…120 (0...960)		24	Syringe dead volume command	

*Operand range limit for C3000 only.

Command	Operand range <n>* ( ) = microstep mode limits	Default operand	Power up default	Command Description	Operand description
Plunger Movement Commands (Note: Argument limits are for C3000 configuration)					
A<n>	0...3000 (0...24000)	0		Move plunger to absolute position	
a<n>	0...3000 (0...24000)	0		Move plunger to absolute position, not busy	
P<n>	0…3000 (0…24000)	0		Relative pickup	
p<n>	0...3000 (0...24000)	0		Relative pickup, not busy	
D<n>	0...3000 (0...24000)	0		Relative dispense	
d<n>	0...3000 (0...24000)	0		Relative dispense, not busy	
Valve Commands					
I	N/A	N/A		Move valve to Input position	
O	N/A	N/A		Move valve to Output position	
B	N/A	N/A		Move valve to the Bypass position	
E	N/A	N/A		Move valve to the Extra position. Valid for 4 position valves only.	
Set Commands					
K<n>	0…100 (0... 800)		10	Backlash steps	
L<n>	1...20		14	Set acceleration/deceleration slope	
v<n>	0...1000		900	Set start velocity in Hz	
V<n>	1...6000		1400	Set top velocity in Hz	
S<n>	0...40		11	Set speed	
c<n>	1...2700		900	Set cutoff velocity in Hz	
h<n>	0...100		10	Set motor hold current in %	
m<n>	0...100		75	Set motor run current in %	
C<n>	0...25		0	Set cutoff velocity in Steps	
N<n>	0...2		0	Set microstep positioning and velocity mode	<0> = Both microstep position and velocity mode off <1> = Microstep position mode on and velocity mode off <2> = Both microstep position and velocity mode on
J<n>	0...7			Sets the 3 TTL auxiliary outputs	0 = all outputs Low 7 = all outputs High
j<ppppn>	<pppp> 1-3000 <n>. .. 0..7			Set Auxiliary outputs based on syringe position	
^<n>	0...255			Non-Functional command	
b	N/A	N/A		Non-Functional command	
EEPROM Commands					
s<n>	0...14			Load program string into EEPROM	
e<n>	0...14			Execute EEPROM string	
U				Set pump configuration parameters	Refer to manual
u	0...16			Set system configuration parameter into EEPROM	For factory use only

*Operand range limit for C3000 only.

Command	Operand range <n>* ( ) = microstep mode limits	Default operand	Power up default	Command Description	Operand description
Report Commands					
Q	N/A	N/A		Report system status	
?	N/A	N/A		Report absolute plunger position	
?0	N/A	N/A		Same as ?	
?1	N/A	N/A		Report start velocity in Hz	
?2	N/A	N/A		Report peak velocity in Hz	
?3	N/A	N/A		Report cutoff velocity in Hz	
?4	N/A	N/A		Report absolute plunger position, same as ?	
?5	N/A	N/A		Same as ?	
?6	N/A	N/A		Reports Valve Position(i, o, b and e)	
?10	N/A	N/A		Report Command Buffer Status, same as F	
?12	N/A	N/A		Report number of backlash steps	
?13	N/A	N/A		Report Status of auxiliary 1 input	
?14	N/A	N/A		Report Status of auxiliary 2 input	
?15	N/A	N/A		Non-Functional, will always report 1	
?16	N/A	N/A		Non-Functional, will always report 1	
?17	N/A	N/A		Non-Functional, will always report 1	
?18	N/A	N/A		Number of valve movements since last ?18, same as %	
?19	N/A	N/A		Reports if pump is initialized with a Y, Z, z or W command. 0 = not initialized 1 = initialized	
?20	N/A	N/A		Report firmware checksum, same as #	
?22	N/A	N/A		Non-Functional, will always return 255	
?23	N/A	N/A		Report firmware version, same as &	
?24	N/A	N/A		Report the syringe's dead volume as set by the [k] command	
?25	N/A	N/A		Motor hold current in %	
?26	N/A	N/A		Motor run current in %	
?27	N/A	N/A		Reports configuration EEPROM data as set using the [u] command	
?28	N/A	N/A		Reports 3 or 4 position valve installed	
?29	N/A	N/A		Current status, same as [Q] command	
?30 - ?44				Reports user EEPROM execution strings, ?30 = s0, ?31 = s1 and so on	
F	N/A	N/A		Report Command buffer status, same as ?10	
&	N/A	N/A		Report firmware version, same as ?23	
#	N/A	N/A		Report firmware checksum, same as ?20	
RZ	N/A	N/A		Report absolute plunger position, same as ?	
RV	N/A	N/A		Report firmware version, same as ?23	
%	N/A	N/A		Number of valve movements since last report, same as ?18	

*Operand range limit for C3000 only.

C-Series CAN Bus Command Summary

Command	Operands	Command Description
On-the fly Commands Frame Type = 0		
V	same as RS232/RS485	Top velocity
T	N/A	Terminate
Action Commands Frame Type = 1		
		All RS232/RS485 commands, with the exception of Report commands, are valid Action commands in CAN bus mode.
Common Commands Frame Type = 2		
0	N/A	Reset mode
1	N/A	Start Loaded command
2	N/A	Clear Loaded command
3	N/A	Repeat last command, like X
4	N/A	Stop action immediately, same as T command
Report Commands Frame Type = 4		
0	N/A	Plunger position
1	N/A	Reports encoder position, like ?4
2	N/A	Same as Report Command 0
3	N/A	Reports valve position, like ?6
4	N/A	Top velocity, like ?2
6	N/A	Start velocity, like ?1
7	N/A	Cutoff velocity, like ?3
10	N/A	Buffer status, like F
12	N/A	Backlash steps, like ?12
13	N/A	Input 1 status, like ?13
14	N/A	Input 2 status, like ?14
15	N/A	Number of pump initializations, like ?15. Note, currently not implemented, will always return a 1.
16	N/A	Number of plunger movements, like ?16. Note, currently not implemented, will always return a 1.
17	N/A	Number of valve movements, like ?17. Note, currently not implemented, will always return a 1.
18	N/A	Number of valve movements since last report, like ?18
19	N/A	Report if pump is initialized. 1 = initialized, 0 = not initialized
20	N/A	Firmware checksum, like ?20
22	N/A	Non-functional command to maintain backward firmware compatibility. Will always return 255.
23	N/A	Firmware version, like &
24	N/A	Syringe dead volume, like ?24
29	N/A	Current status, like Q